Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

DECEMBER, 1956

TECHNOLOGY DEPT.

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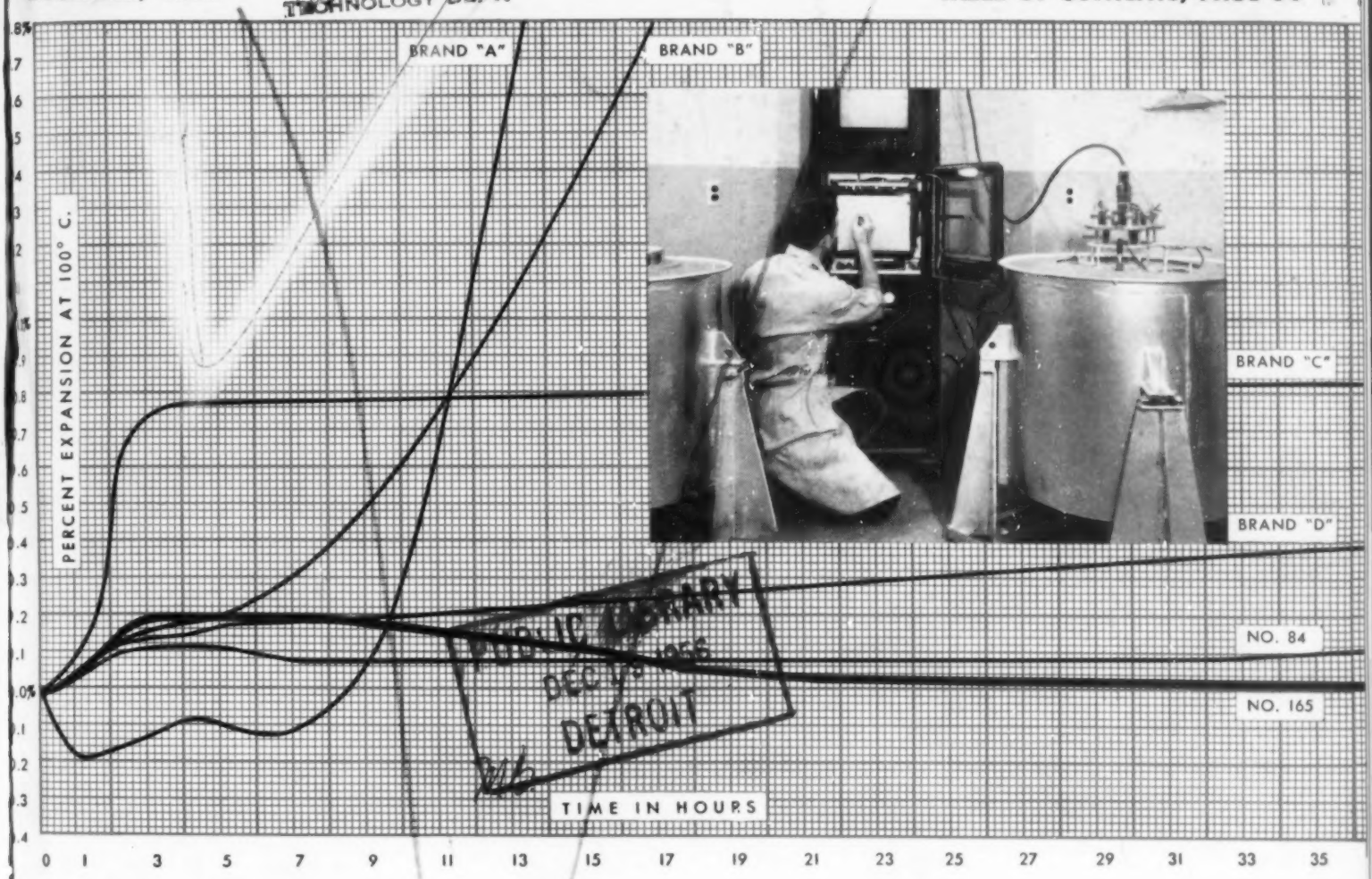


PUBLIC LIBRARY DETROIT

DILATOMETER VOLUME STABILITY TEST:

"SOAK AND SWELL" CHART shows why Permanente 165 Ramming Mix gives longest-life furnace bottoms

HYDRATION—reaction with water—during the heat-up period usually causes swelling of rammed magnesia bottoms. Leading ceramic engineers believe that as little as 0.3% expansion indicates damaging hydration, shorter bottom life.

To measure these minute expansions, Kaiser Chemicals Research developed the sensitive electronic instrument shown above. This device, called a dilatometer, can accurately measure and record expansions of less than 0.01% and maintain a constant temperature within ±0.5°C.

Dilatometer Trace Charts

For the test charted above, equal size blocks freshly prepared from each of six well-known ramming mixes were placed in a common heating chamber and attached to the recorder.

The chamber was then heated to just below the boiling point of water with the atmosphere held at 100% relative humidity to create forced hydration conditions. Finally, the samples were allowed to soak for 35 hours to simulate hydration conditions which a mix may encounter in the deeper regions of a bottom.

As you can see in the chart, Permanente 165 shows virtually no signs of expansion . . . proof that it resists hydration significantly better than any other ramming mix tested. (Permanente 84 Hot Patching Mix runs a very close second.)

Research Aids Bottom Performance

Permanente 165's outstanding resistance to hydration is an excellent example of how Kaiser Chemicals Research is working to give you furnace bottoms that last longer, need fewer repairs. Why not let your Kaiser Chemicals Sales Engineer provide research, design and installation assistance to help you take advantage of this superior ramming mix?

Call or write Kaiser Chemicals Division, Dept. R6421, Kaiser Aluminum & Chemical Sales, Inc., at any of the addresses listed below:

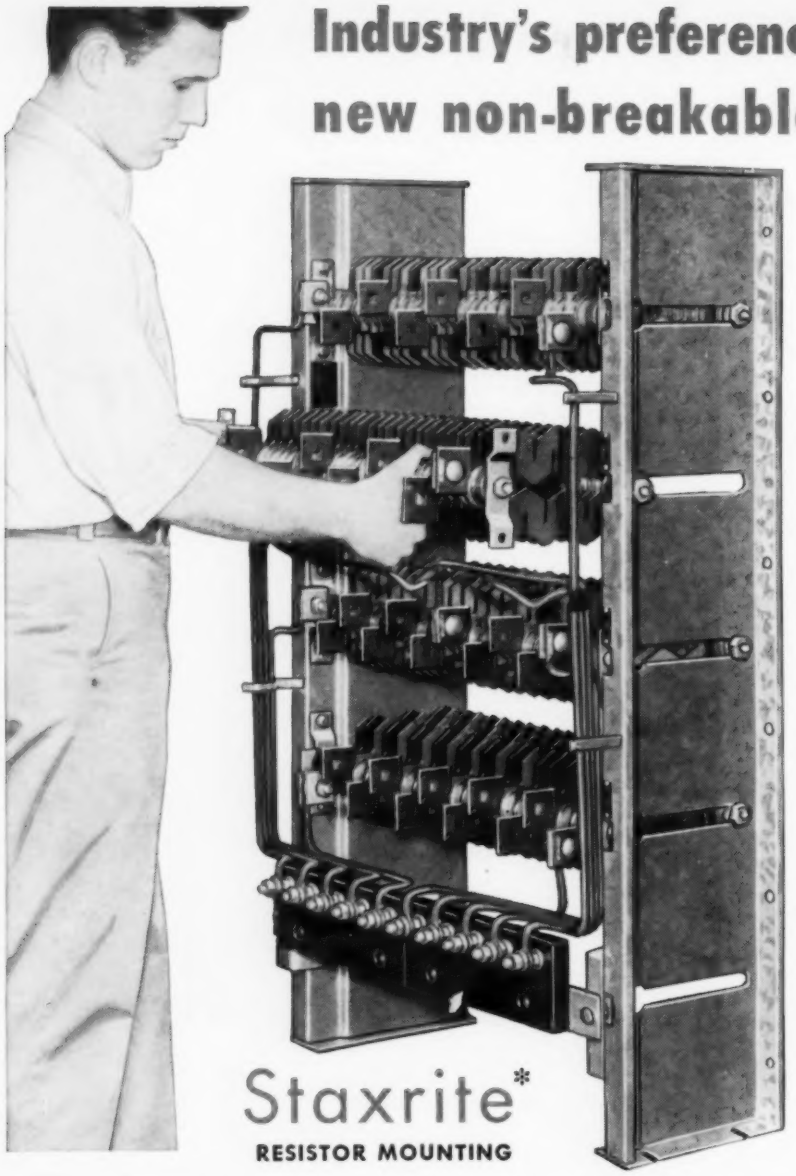
PITTSBURGH 22, PA. . . . . 3 Gateway Center
HAMMOND, IND. . . . . 518 Calumet Building
OAKLAND 12, CALIF. . . . . 1924 Broadway

Kaiser Chemicals

Pioneers in Modern Basic Refractories

REFRACTORY BRICK AND RAMMING MATERIALS • CASTABLES & MORTARS
MAGNESITE • PERICLASE • DEADBURNED DOLOMITE

Industry's preference... Cutler-H ...er's new non-breakable Mill Duty R ...tor



Cuts costs during installation, maintenance and alterations. Exclusive C-H "Draw-out" designed resistor units slide in and out of position easily and quickly without disturbing the end frames, adjacent resistor units or mounting members. "Draw out" design cuts costly "down time" to a minimum. Any resistor can be withdrawn and replaced by a spare in a few minutes.

Difficult resistor mounting problems made easy with Staxrite. Saves valuable space ... Staxrite mounting frame, available in graduated sizes up to nine resistor units high, only requires the floor area of one resistor box. Complete terminal board wired assemblies practically eliminate costly on-the-job wiring. Unwired assemblies also available.

Exclusive "Draw-out" Design and Staxrite, the All New Resistor Mounting Frame, Have Made the Cutler-Hammer 11011 Mill Duty Resistors the Choice of Men Who Know

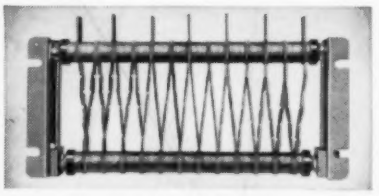
Cutler-Hammer, leading mill control designer and manufacturer for 63 years, is "first" again with "Draw-out" designed mill duty resistors and Staxrite, the multiple resistor mounting frame. Cutler-Hammer's 11011 resistor featuring exclusive "Draw-out" design, installs easier, works better and lasts longer.

The C-H 11011 resistors are non-breakable, rugged, vibration proof, and corrosion proof. Staxrite, a new concept in resistor mounting, offers new savings in space ... More resistor material for each square foot of floor area. Staxrite saves installation time. No more box-by-box mounting. For complete information on the C-H 11011 non-breakable resistor, Staxrite mounting frame and all types of mill duty control, write or wire today. Your inquiry will receive prompt attention.

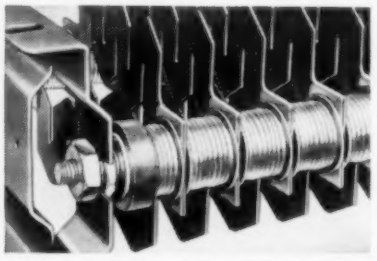
CUTLER-HAMMER, Inc., 1269 St. Paul Avenue, Milwaukee 1, Wisconsin. Associate: Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

*Staxrite is a Cutler-Hammer Trademark

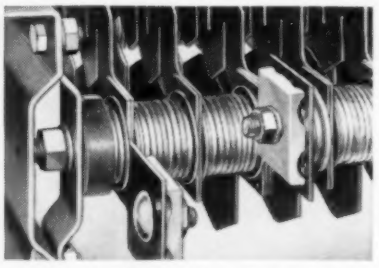
Accurate current and voltage regulation—Stamped chrome-steel grids (not cast) maintain a fixed, reliable resistance value ... a must for machinery requiring precise regulation. Shock-proof, vibration-proof, corrosion-resistant and non-breakable.



Higher current capacities—Unique "over-under" grid pattern allows wider clearance between grids for maximum air circulation and rapid, sure heat dissipation. C-H resistors work harder. C-H resistors last longer.



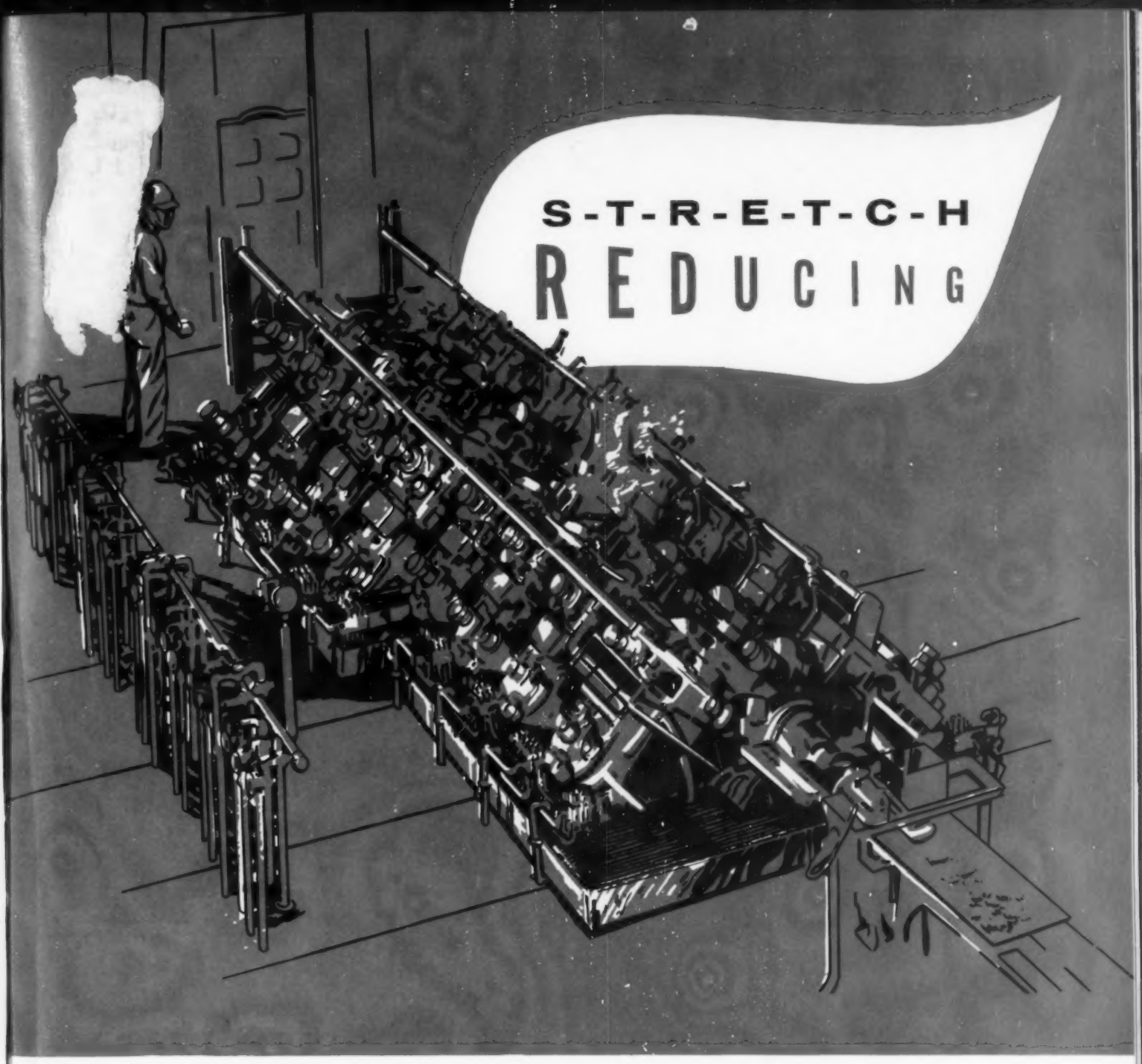
More rugged but less weight—Welded grid joints form a rugged, continuous current path. No more heavy grid tie-rods. No more pressure dependent grid contacts. Note—New floating rod construction eliminates grid stresses and distortion due to thermal expansion.



Easy to wire terminals—Hefty projected terminals are staggered for wiring simplicity. Terminal-grid weld insures positive electrical contact—can't shake loose. Note the steel spacing washers and heavy-duty mica insulators ... the mark of sturdy, rigid resistor construction.

CUTLER-HAMMER
MOTOR CONTROL
C-H

IRON AND STEEL ENGINEER; published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., Pittsburgh, Pa. Second class mail privileges authorized at Pittsburgh, Pennsylvania, January 25, 1924.



● Much of the news in Seamless concerns the Stretch Reducing principle. The first such mill was installed by National Tube Division of U. S. Steel Corporation. Aetna-Standard collaborated with National Tube in designing this mill and supplying the equipment. Since that time, much development work has been done on the equipment and the process.

Chief advantage of the Stretch Reducing method is the resulting increase in tonnage from existing Seamless Tube Hot Mill equipment for the production of A. P. I. steel tubing. Briefly, tubes of the larger O. D. (6″ to 7″) are produced through the existing Piercer, Plug Mill and Reelers, thereby obtaining a maximum number of tubes at an increased tonnage per operating hour.

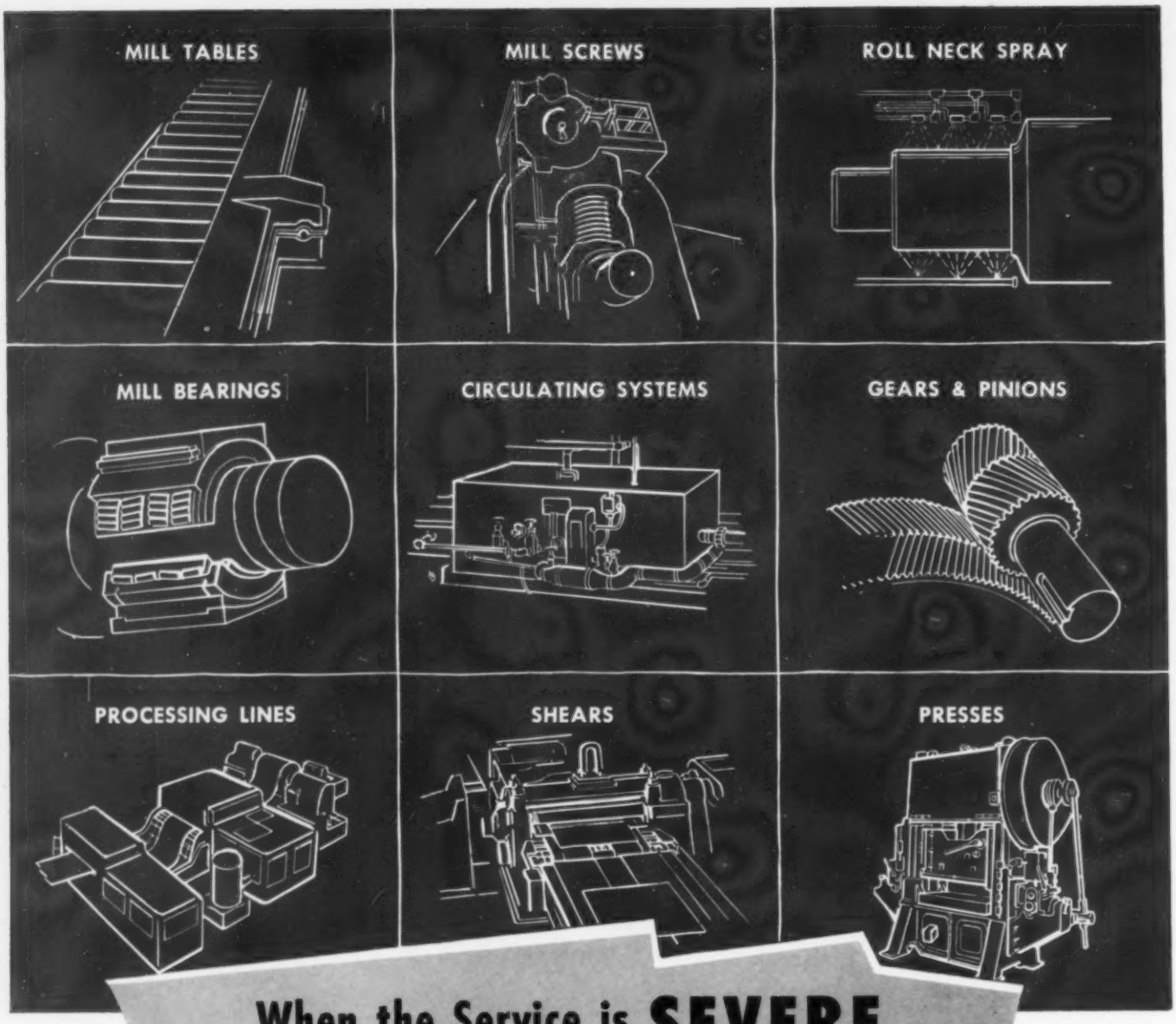
Aetna-Standard has built and is building most of the Stretch Reducing mills. If your group needs facts on cost, design, yield and other information, Aetna's Seamless engineers can help you.

AETNA • STANDARD

THE AETNA-STANDARD ENGINEERING COMPANY

GENERAL OFFICES: PITTSBURGH, PA. **PLANTS: ELLWOOD CITY, PA., WARREN, OHIO**

CONTINUOUS GALVANIZING LINES • CONTINUOUS ELECTROLYTIC TINNING LINES • SIDE TRIMMING AND SHEAR LINES AND OTHER FINISHING EQUIPMENT • CONTINUOUS BUTT WELD PIPE MILLS • SEAMLESS TUBE MILLS • DRAWBENCHES AND OTHER COLD DRAW EQUIPMENT • ROLLS AND CASTINGS



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The unique properties of Brooks lubricants have provided outstanding service where other quality lubricants have proved inadequate. Brooks lubricants are remarkably resistant to water or moisture conditions and abrasion. Brooks lubricants are non-corrosive, adhesive, and extremely stable in long periods of production service; maintaining a *minimum* pH-ilm strength of 25,000 psi. Extended equipment service and reduced lubricant consumption can be assured in practically all severe applications.

Write for Engineering Data Bulletin on your particular application.

THE BROOKS OIL CO. 80th YEAR 1876 1956

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THE BROOKS OIL STORY
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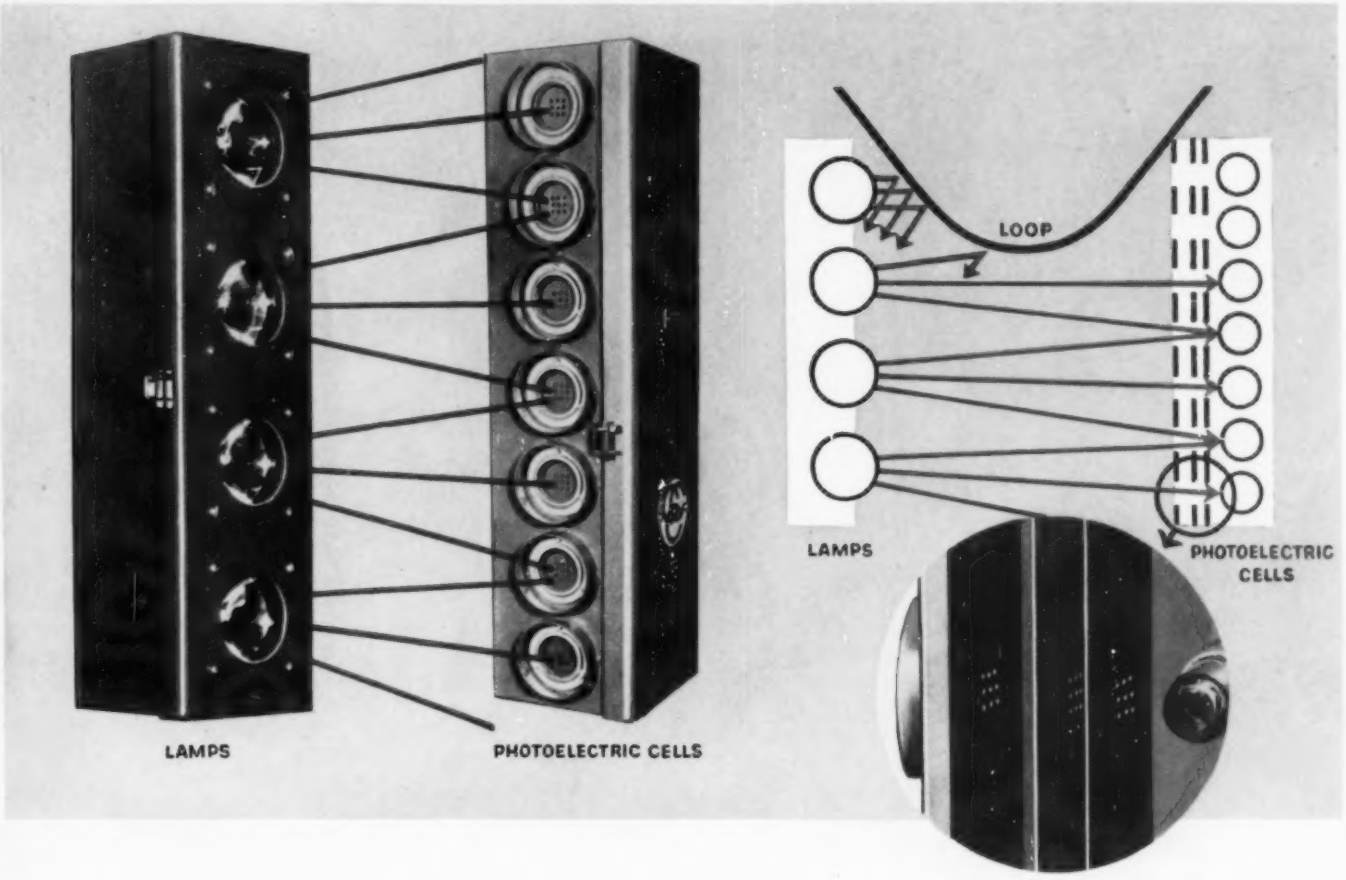
Banish "Outside" Light Troubles WITH NEW CLARK LOOP CONTROL



Only light from control lamps can reach the sensitive photo-electric cells.

Here's how it works:

The basic principle of electronic loop control is simple. A bank of lights on one side of the loop is directed toward a matching bank of photo-electric cells on the opposite side. The loop, hanging between them, interrupts some of the light. As the loop position changes, more or less light is interrupted, depending upon whether the loop is lengthened or shortened. Signals from the cells are amplified by a Clark Magnetic Amplifier and transmitted to controls that regulate drive speed to maintain the loop position within close limits.

Light from outside sources can adversely affect the operation of ordinary electronic loop control. Floodlights, workers' flashlights, lights from cranes—even reflections from shiny strip—have often produced costly cobbles.

In this new Clark Loop Control, each photo-electric cell is shielded by three grids, consisting of metal plates with holes permitting light only from the loop control lamps to reach the cells. The pattern and placement of the holes, and the spacing of the grids, is carefully determined so that light from each lamp falls on several cells. Thus, interruption from a changing loop causes a change in strip speed to correct the loop error. This, plus other exclusive Clark features, assures completely "stepless" loop control.

This is another example of greater operating efficiency through Clark-engineered Control.

The **CLARK** **CONTROLLER** *Company*

Engineered Electrical Control

1146 East 152nd Street • • Cleveland 10, Ohio

IN CANADA: CANADIAN CONTROLLERS, LIMITED • MAIN OFFICES AND PLANT, TORONTO

new

REMOTE CONTROL

manipulator

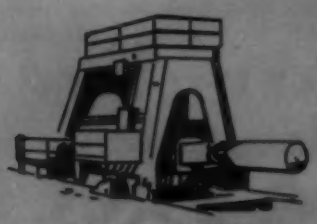
BY ALLIANCE

The manipulator of tomorrow—for today's modern plant! Alliance leads the way in imaginative engineering of heavy machinery for the iron and steel industry.

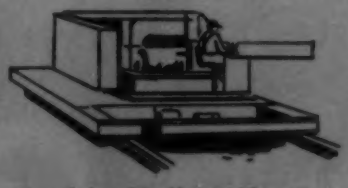
GIVE US THE RUNWAY AND
WE'LL LIFT THE WORLD

Alliance

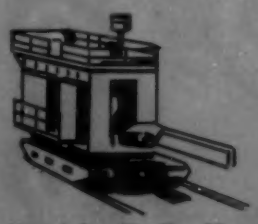
LADLE CRANES • GANTRY CRANES • FORGING MANIPULATORS • SOAKING PIT CRANES • STRIPPER CRANES • SLAB AND BILLET CHARGING MACHINES • OPEN HEARTH CHARGING MACHINES • SPECIAL MILL MACHINERY • STRUCTURAL FABRICATION • COKE PUSHERS



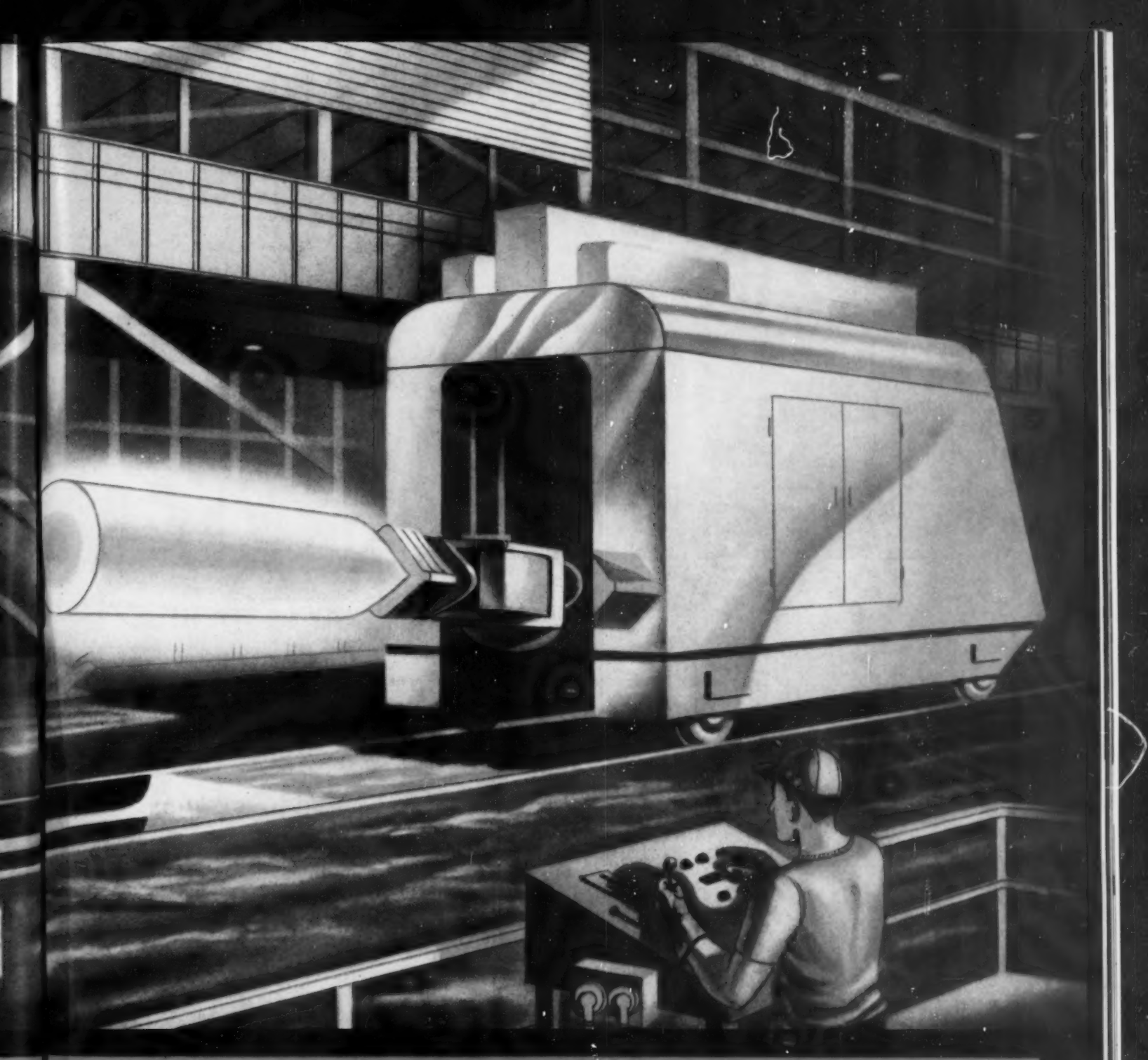
Straight Line Manipulator



Revolving Trolley Bridge Type



Revolving Trolley Type



handles billets faster, easier...

● The Alliance remote control manipulator requires only pushing a button to move a billet into position for any forging operation. Finger-tip electrical and hydraulic controls do the work.

The operator sees the operation better, and stays alert longer because he is free of physical strain.

Modern design and elimination of the operator's platform reduces manipulator weight to a minimum. It handles any size and weight billet faster and easier, combining faster acceleration with less inertia.

Put Alliance engineers to work on your heavy machinery requirements. Alliance is the world's largest builder of the world's largest cranes.

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MAIN OFFICE • ALLIANCE, OHIO

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OUR CONSCIENTIOUS SERVICE – is a *plus* factor!

Our service engineers are thoroughly familiar with electrothermic and electrochemical operations. They are competent to render high level technical advice to electrode, anode, carbon brick and mold stock customers.

The alertness of these service engineers in anticipating customer needs and wishes is a characteristic *plus factor* in the trustworthiness of GLC carbon and graphite products.

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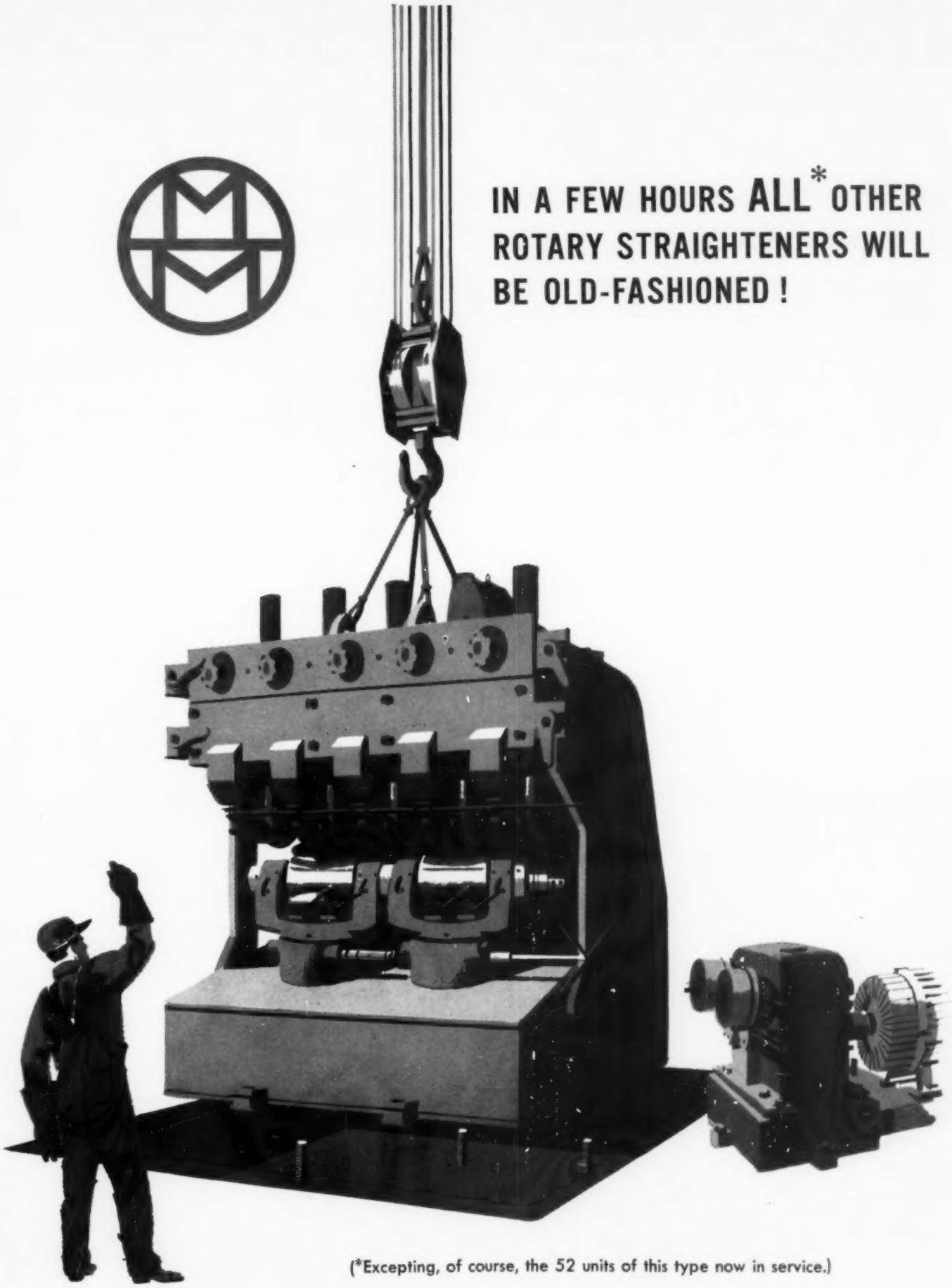
IN A FEW HOURS ALL* OTHER ROTARY STRAIGHTENERS WILL BE OLD-FASHIONED !



(*Excepting, of course, the 52 units of this type now in service.)

MANNESMANN – MEER Engineering and Construction Company, Inc., 900 Line Street, Easton, Pennsylvania

SIXTH OF A SERIES

Customer's Report

"We cut our Process Inventory by 40% when we switched to single stack annealing"

The cost of process inventory is just as much a capital investment in the annealing department as are the furnaces, buildings, etc. For example, one customer with a 50,000-ton-per-month operation found the Lee Wilson Single Stack Furnaces required $500,000 less in process inventory than did an equivalent four stack installation. A 40 percent reduction!

The answer: Lee Wilson Single Stacks have a much higher production rate. Using Single Stack furnaces, six pedestals can do the work required of 10 pedestals where four stack furnaces are used. This means fewer pedestals are needed to anneal a given tonnage, and correspondingly less steel required in the annealing department.

Here are dollars you cannot afford to overlook! Why not have a Lee Wilson engineer fill you in with all the facts on the most efficient annealing furnace ever developed — The Lee Wilson Single Stack.

Only Lee Wilson Furnaces Give You All These Advantages

1. GREATER FLEXIBILITY
2. MORE UNIFORM HEAT APPLICATION
3. IMPROVED CUSTOMER SERVICE
4. HIGHER PRODUCTION
5. BETTER LOAD FACTOR
6. MINIMUM PROCESS INVENTORY
7. REDUCED LABOR COST
8. BETTER OPERATING CONDITIONS
9. LOWER MAINTENANCE COST
10. REDUCED INSTALLATION COSTS

Lee Wilson* **ENGINEERING COMPANY, INC.**

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SINGLE-STACK RADIANT TUBE ANNEALING FURNACES

MAKE THE BEST METALS BETTER

* ORIGINATORS AND LEADING PRODUCERS OF SINGLE-STACK RADIANT TUBE FURNACES

The trend is to single stack. One of the nation's largest annealing departments recently put into operation 24 Lee Wilson Single Stack Furnaces and 72 bases.

Specify... **J-M Asbestos Wick** **J-M Asbestos Rope**

Wherever you need general utility packings that are easy to handle, highly heat resistant

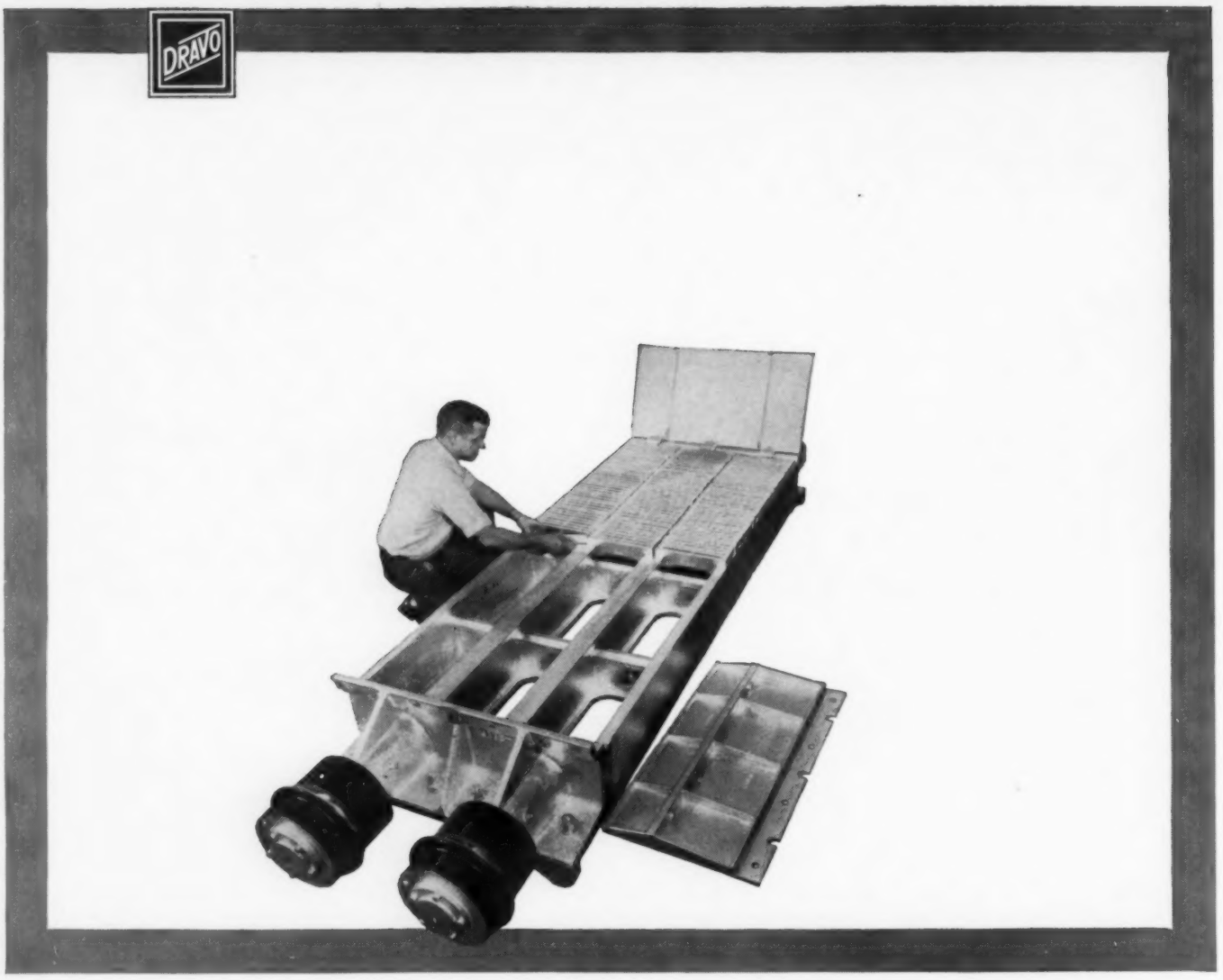
Throughout the iron and steel industries, the list of uses for Johns-Manville Asbestos Wick and Rope is constantly growing. These soft, resilient, heat-resisting materials are widely employed for general packing, gasketing and caulking applications.

In coke ovens, both are used to caulk around the doors to prevent the escape of gases. Asbestos Rope (Style 4200) also serves as expansion joint material in the brickwork.

Only a few of the many applications for Asbestos Wick (Style 4202) can be given here. It seals hot metal in the ingot mould, around the top and between the mould and the stool. It gives protection from burning to water hoses that cool Open Hearth doors. It serves as a seal between the cope and drag on moulding flasks. It is used to wipe excess coating from wires after passing through the galvanizing bath.

Styles 4200 and 4202 are made from pure asbestos fibre carefully controlled for quality at Johns-Manville's own mine and mill (largest in the world). Asbestos Rope is formed by twisting together two or more strands of Wick to obtain the desired thickness. For further information, call your local J-M distributor or write Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

Johns-Manville PACKINGS, GASKETS and TEXTILES



DRAVO-LURGI

sintering experience . . . ready to work for you

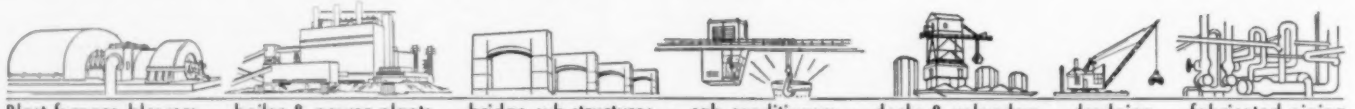
More than 250 sintering plant installations qualify Lurgi as Europe's oldest and foremost designer of equipment for the treatment of low grade ore. In fact, the total capacity of Lurgi sintering machines now processing iron ore alone is in excess of 30 million tons annually.

An exclusive license agreement enables Dravo to adapt these advanced designs to the needs of American industry.

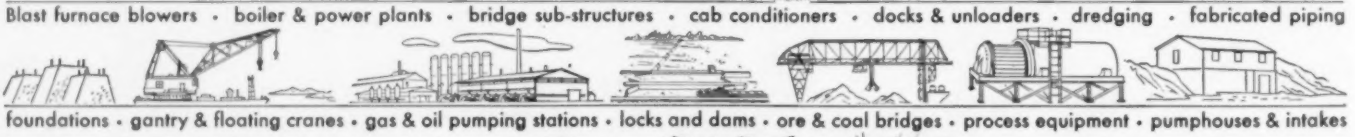
In a major installation recently completed by Dravo, 124 pallets, like the one shown above, are used. Design features of these pallets are the result of Lurgi's 30 years' experience in sintering machinery construction.

Engineering and planning assistance is available to help you develop equipment or complete plants for sintering, pelletizing or other related ore processing and preparation. Write to Dravo Corporation, Dept. S-100, Pittsburgh 22, Pa.

DRAVO
CORPORATION

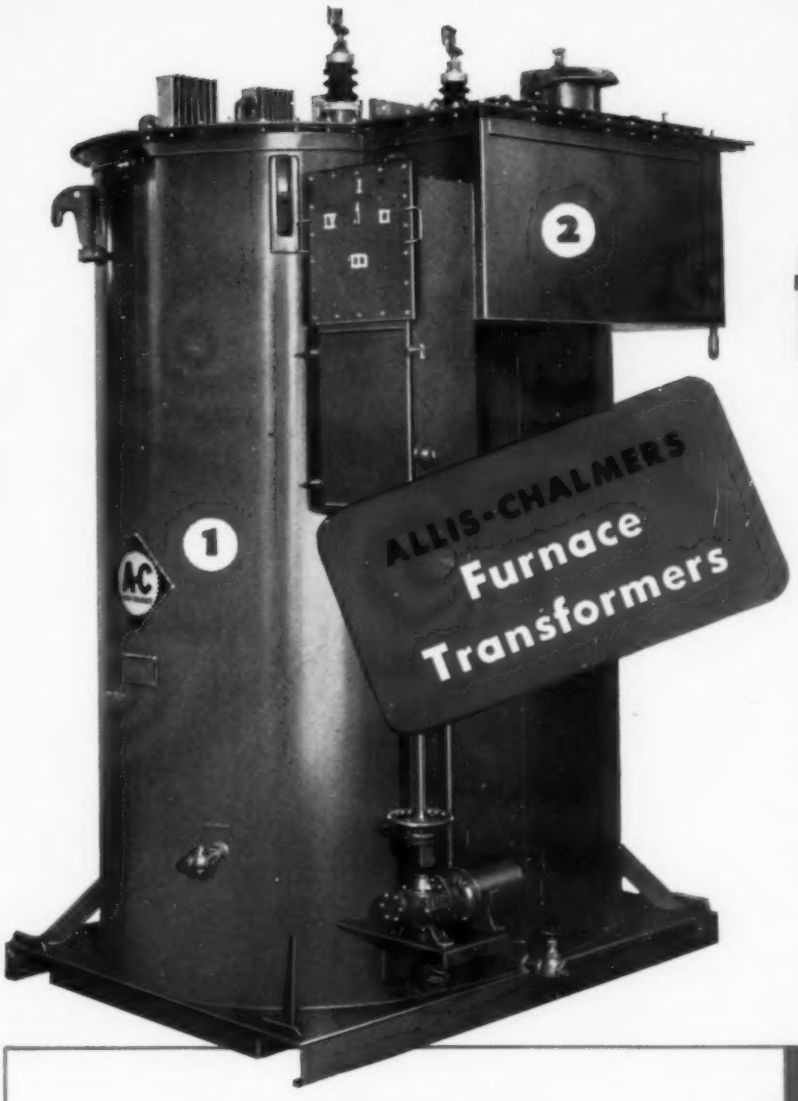


Blast furnace blowers • boiler & power plants • bridge sub-structures • cab conditioners • docks & unloaders • dredging • fabricated piping



foundations • gantry & floating cranes • gas & oil pumping stations • locks and dams • ore & coal bridges • process equipment • pumphouses & intakes

river sand and gravel • sintering plants • slopes, shafts, tunnels • space heaters • steel grating • towboats, barges, river transportation



4 Extras for Tough Jobs

Check features based on over 30 years' experience building arc furnace transformers

Features like these help Allis-Chalmers arc furnace transformers stand up under strain of repeated daily short circuits . . . the heat of high continuous currents . . . the corrosive atmosphere of the plant.

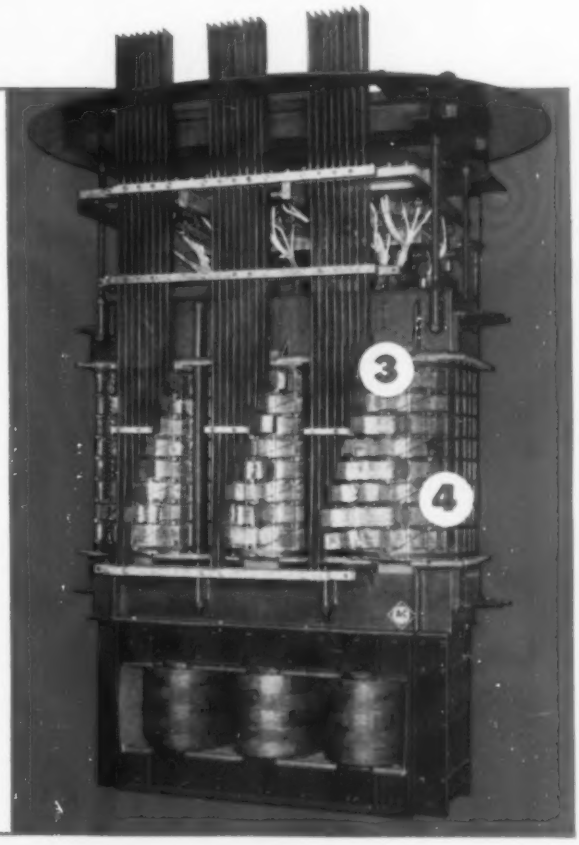
Extra Features —

1 ***EXTRA*** **SURFACE PROTECTION** — Grit blasting and three coats of baked-on alkyd resinous paint guard transformers against industrial corrosion.

2 ***EXTRA*** **ACCESSIBILITY** — Separate compartment for tap changer mechanism facilitates periodic inspection and maintenance.

3 ***EXTRA*** **STRENGTH SUPPORTS** and structure brace coils against severe short-circuit stresses.

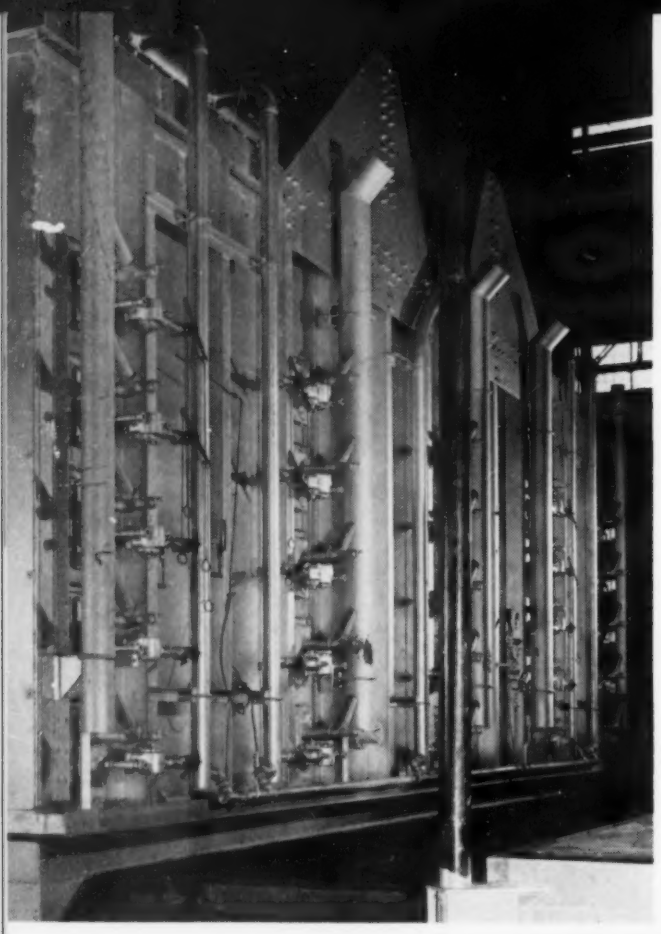
4 ***EXTRA*** **PROTECTED WINDINGS** — Special insulation techniques protect winding from overvoltage due to wide tap range.



Complete Line of Arc Furnace Electrical Equipment Allis-Chalmers builds arc and submerged arc furnace transformers of all sizes, plus electrical control, circuit breakers and auxiliary transformers. For help on your problem, call your nearby A-C office or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin.

A-5086

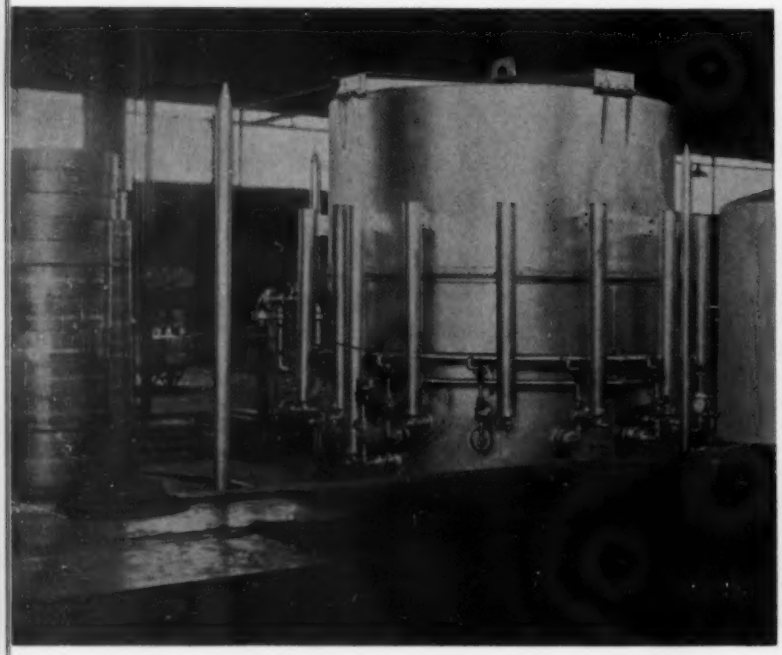
ALLIS-CHALMERS

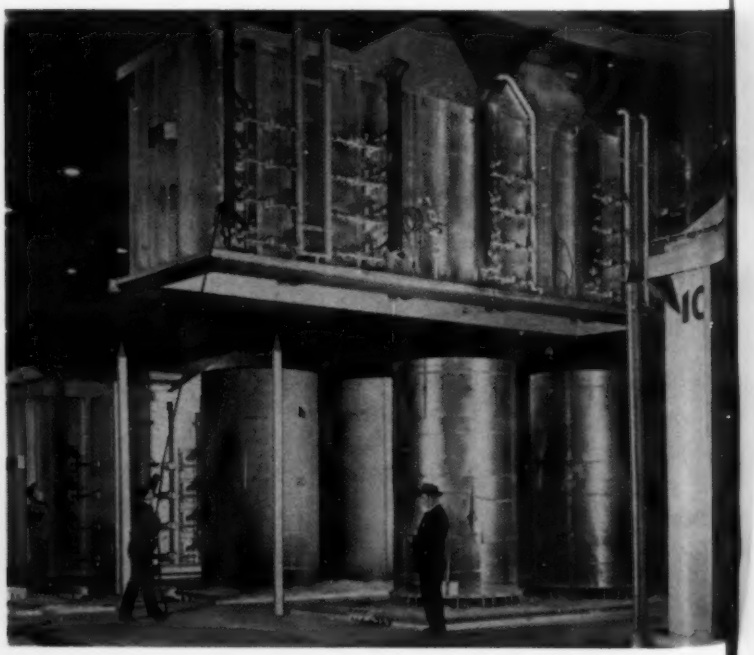


FOR
GENERATIONS
IN
STEEL

The top standard of excellence
in sheet and strip annealing

SWINDELL

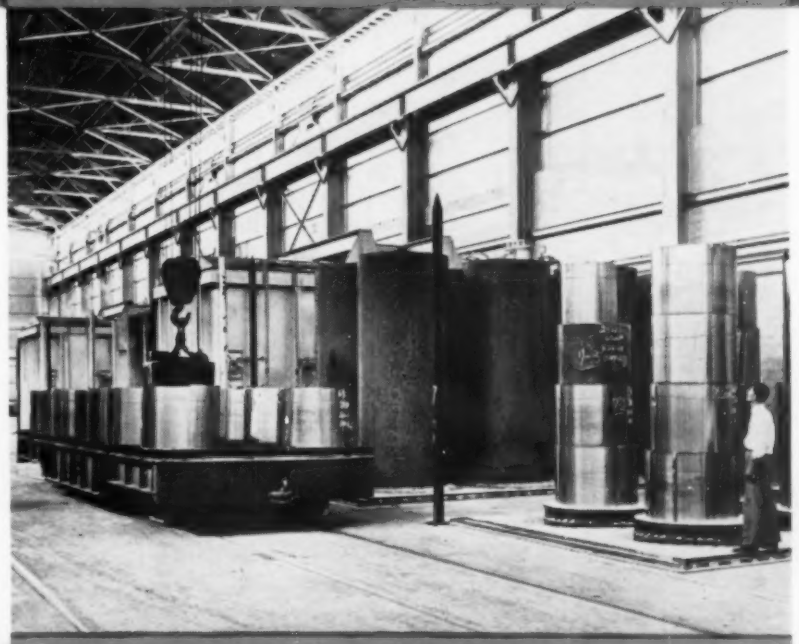




INDUSTRIAL FURNACES

Since 1850

In design, construction and performance SWINDELL Annealing Furnaces set the pace in tonnage handling for America's largest sheet and strip producers. • Decade after decade, steady technological advances keep Swindell in the forefront of heating progress—and year after year, long-lived Swindell dependability returns dividends on every furnace investment. • For helpful consultation on your annealing requirements, write us.



SWINDELL-DRESSLER *Corporation*

DESIGNERS AND BUILDERS OF INDUSTRIAL FURNACES

PITTSBURGH 30, PENNSYLVANIA

8 good reasons why you should use these ROLLER GUIDES in your bar or wire rod mill

Nos. 125 and 155 roller guides fitted in a 27 1/2 in. (700 mm.) diameter, three-high stand for rolling 2 3/4, 3 3/16, 3 9/16, 4, 4 3/8 and 4 7/8 in. (70, 80, 90, 100, 110 and 124 mm.).

1 The entry friction guides are rigidly clamped into the guide box. They are intended to lead the oval to the groove in the roller, to protect the rollers against overloading, and to straighten bent rods.
The groove in the entry guides is made about 1/8" wider than the oval.

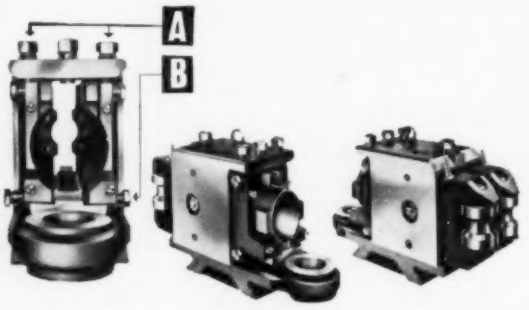
2 The rollers are mounted on leaf springs, which can be adjusted by means of the screws "B", and hold the oval steadily even if there should be some slight variation in the thickness of the oval.

3 If the thickness of the oval should vary, the springs of both rollers yield an equal amount, so that the oval remains in the centre of the groove.

4 To tilt the oval, the screws "A" are adjusted. One roller will then be lifted as much as the other is lowered.

5 As the oval is held very rigidly, the leader oval for wire rod may be thick, unless other circumstances call for a thinner oval.

6 The roller guide assemblies are narrow, and all screws that require adjustment during rolling are accessible from the front of the mill. No lateral space outside the guide box is therefore required for gaining access to the set screws, and the guide box assembly can thus be located close to the mill housing.



7 As the groove in the entry guides is wide and nothing but rolling friction acts on the oval, the latter is very easily introduced into the pass, and there is practically no risk of scratching the bar.

8 The roller guide may be used not only for leader and drawing oval passes but also for edging flats as well as for rolling squares, hexagons, octagons and various other sections, for instance in reduction passes for hexagon. It is suitable for all types of rolling mill. An important advantage is that the roller guide enables repeaters to be used in rolling plump leader-ovals.

PS *Practically speaking, every bar and wire rod mill in Scandinavia uses roller guides of our design.*

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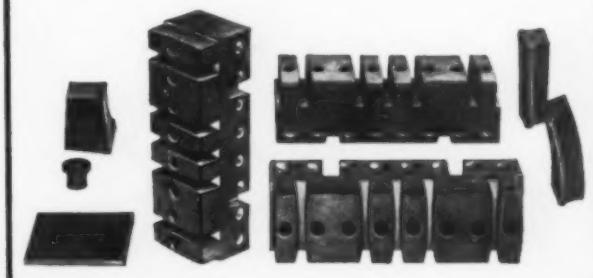

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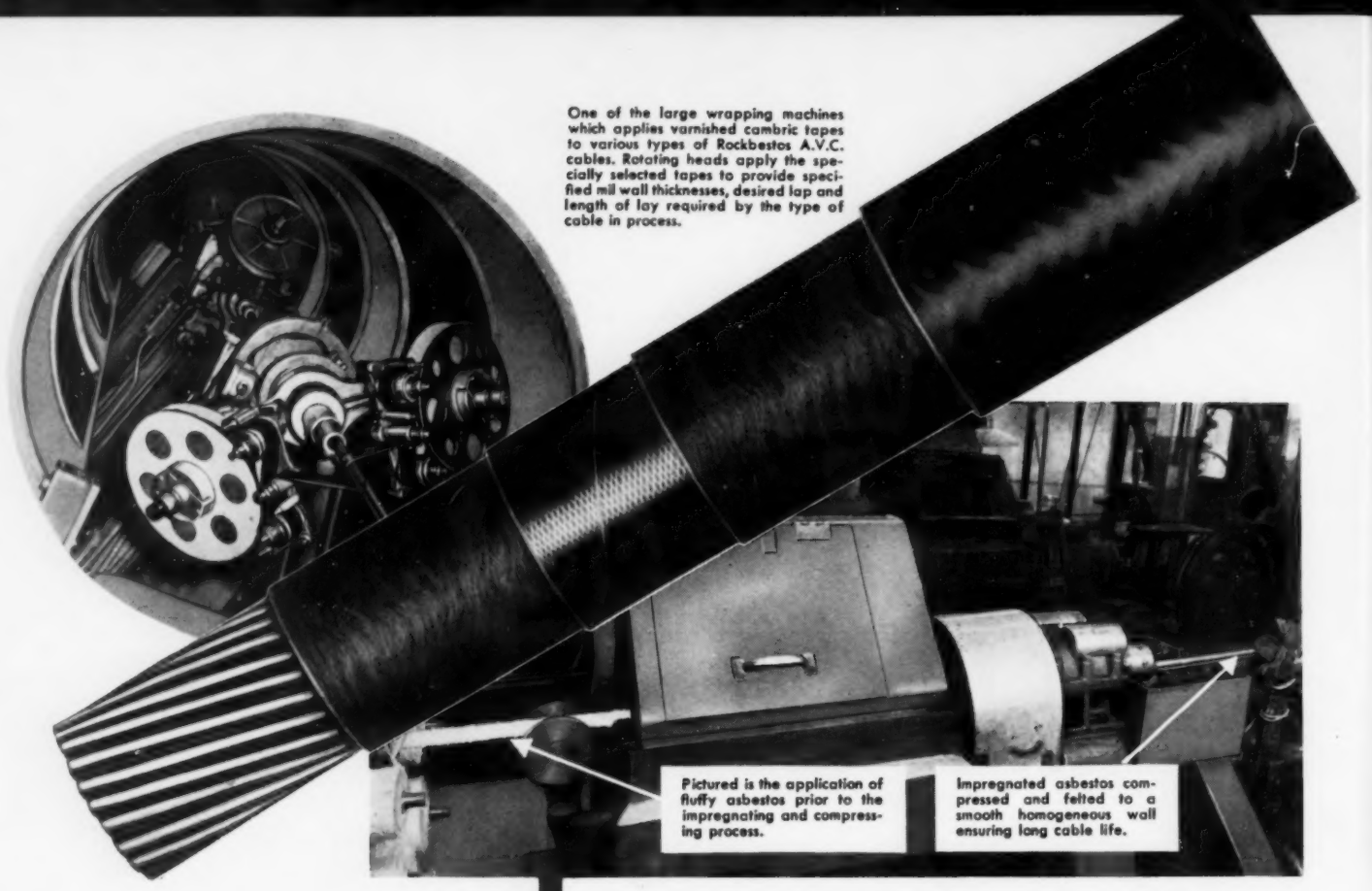

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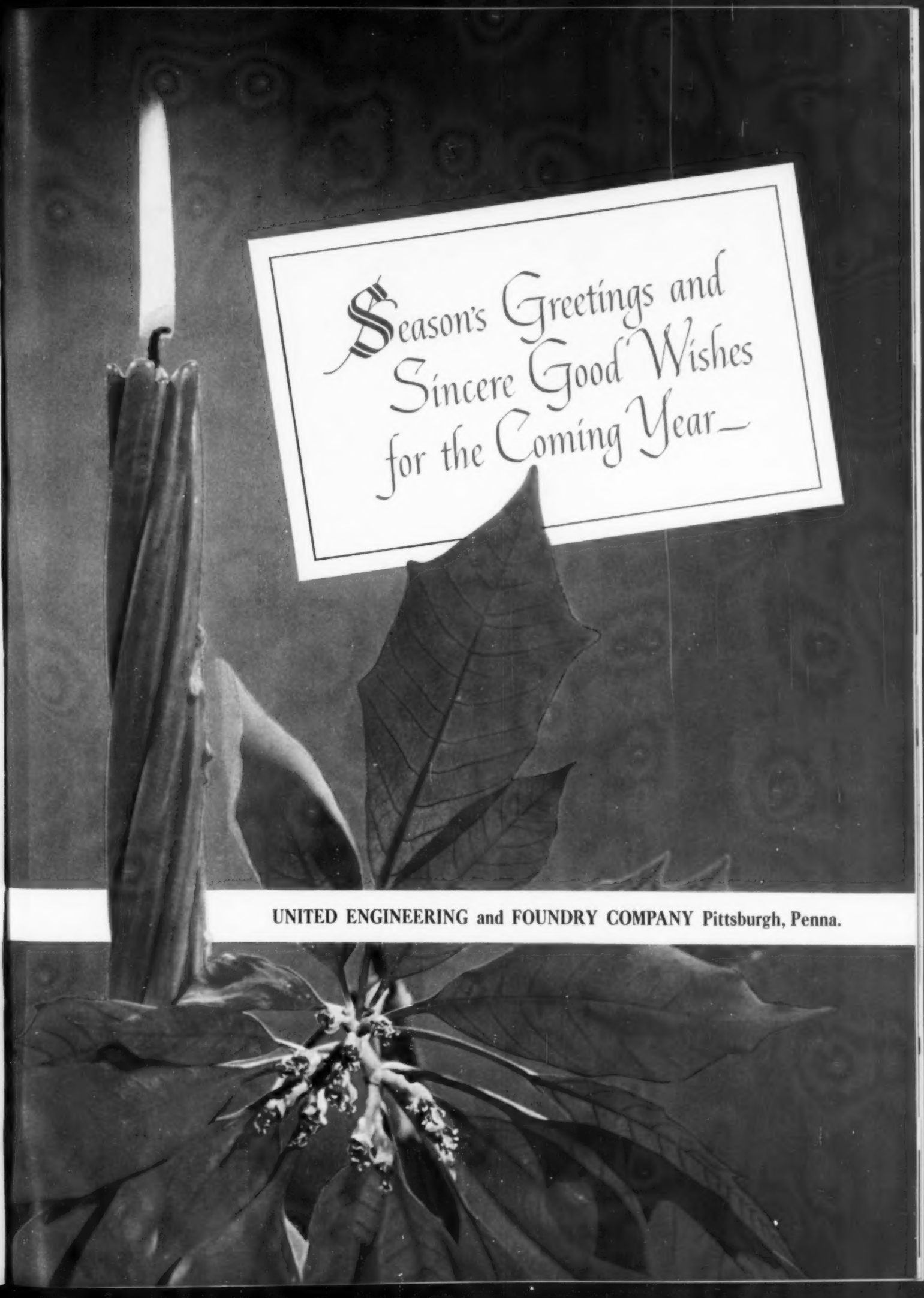

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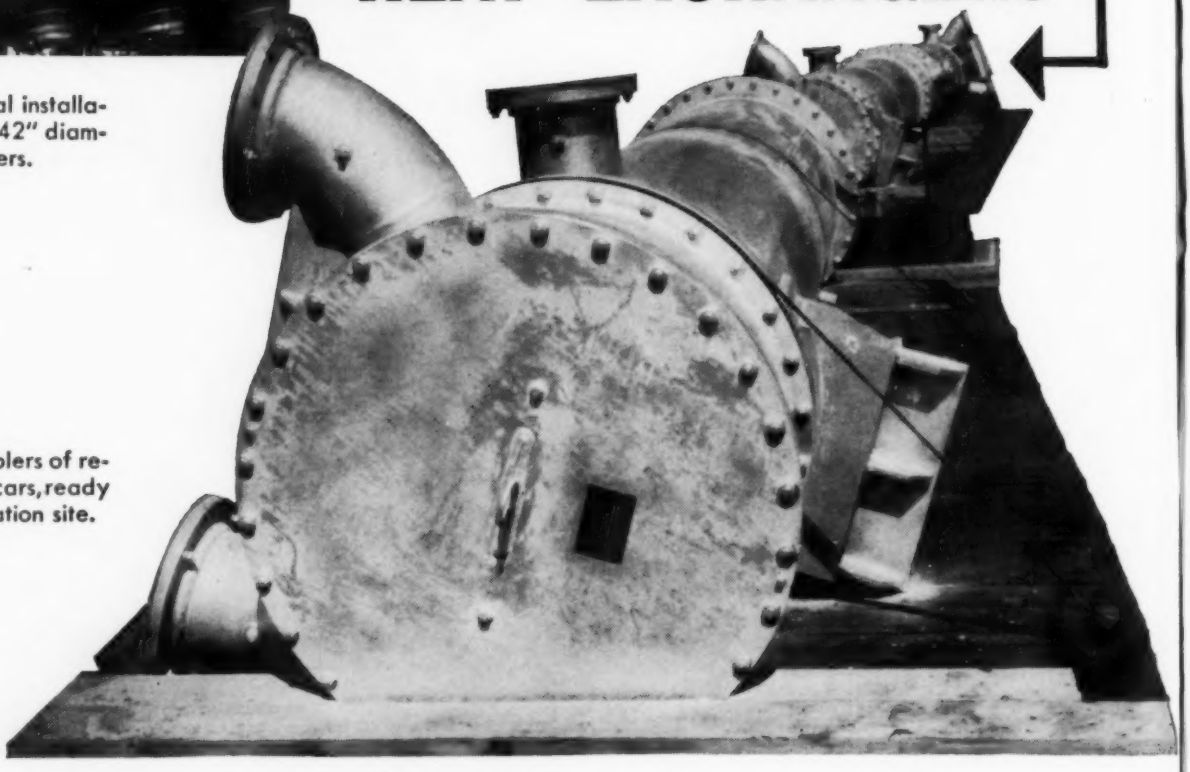

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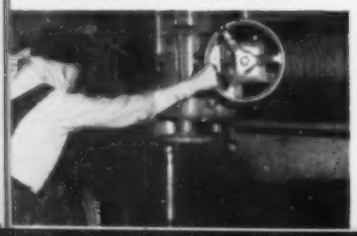

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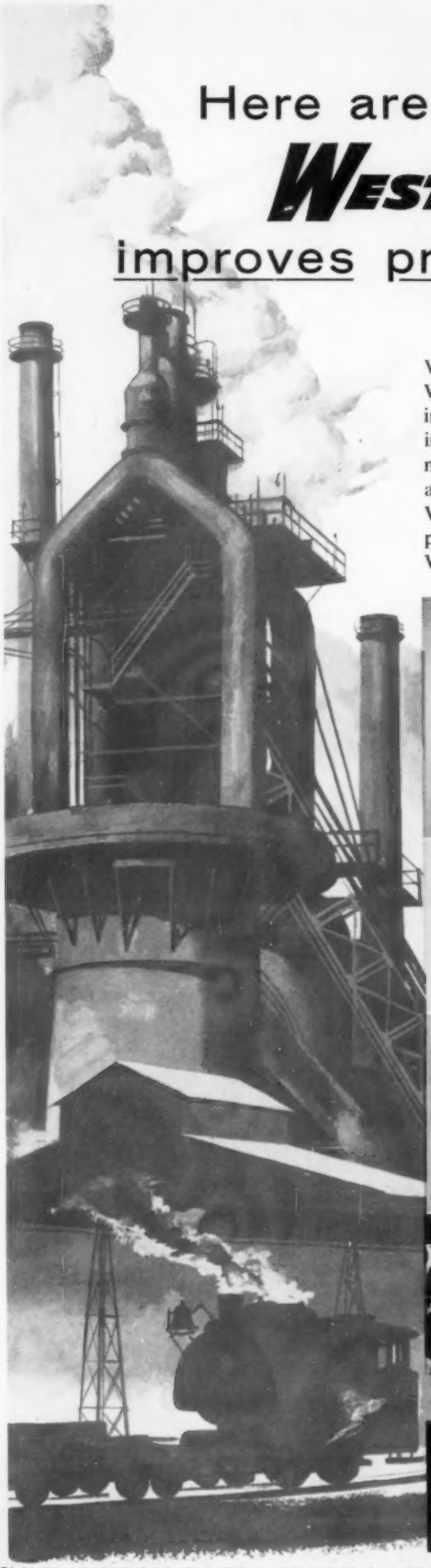

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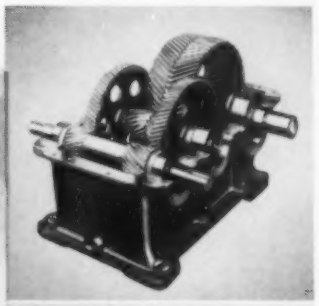
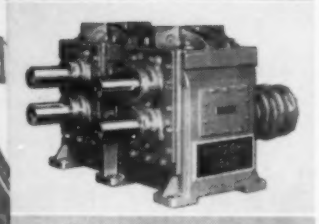
Write: General Offices, Western Gear, P.O. Box 182, Lynwood, California.



Speed Reducers Wherever you find efficient steel production, you are apt to find the mill relying on Western Gear to provide its speed reducer needs. Capacities of these units range to 10,000 HP. As a result of years of successful service to the industry, Western Gear speed reducers are utilized on main mill drives and auxiliary drives in steel mill centers everywhere. Western Gear reducers are also used on cranes, for trolley, bridge and hoist drives as well as all types of conveyors.



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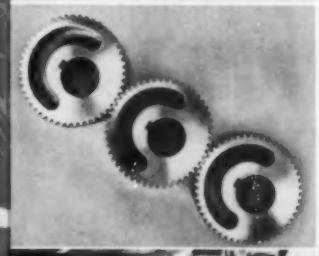

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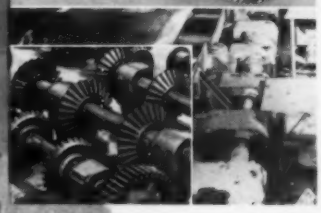

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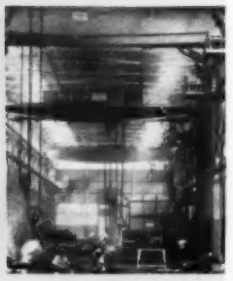

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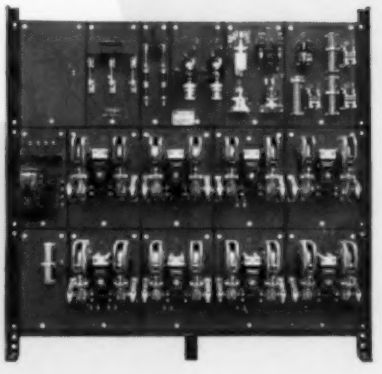

• Here's another example of preference for EC&M *Engineered* Crane Control for industry's tough and critical handling jobs. For its new foundry, The Bullard Company, large eastern machine tool builder, selected EC&M Control for 11 new cranes powered by A-C motors. A thorough study of EC&M apparatus and engineering showed that EC&M circuits were the safest, simplest, and that speed-torque curves of EC&M's EDDYMAG Hoist Control were the finest available. Acceleration by the EC&M Frequency Relay Method was another plus value.

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By MELVIN NORD, Patent Attorney, Detroit, Mich.

Patent Reviews

. . . . copies of patents may be obtained from the Commissioner of Patents, Washington 25, D. C., at 25 cents . . . . patents reviewed cover period July 3, 1956 through July 31, 1956 . . . .

OPEN HEARTH FURNACE CONSTRUCTION

▲ U.S. 2,753,171, issued July 3, 1956 to Russell P. Heuer and assigned to General Refractories Co., relates to the construction of uptakes, slag pockets, and division assemblies or dog houses for open hearth furnaces. The object of the invention is to facilitate the removal of foreign matter from the slag pocket and avoid or minimize the slagging of refractory brick in the uptakes.

METHOD AND APPARATUS FOR MAKING BELTS FROM STEEL STRIP

▲ U.S. 2,752,670, issued July 3, 1956 to Edwin T. Lorig, and assigned to United States Steel Corp., describes a method and apparatus for making a belt from a length of cold rolled steel regardless of the amount of camber in it, without cutting or patching lengths of strip together.

MULTIPLE PASS CHECKWORK

▲ U.S. 2,753,172, issued July 3, 1956 to George P. Reintjes, relates to checkerwork used in connection with open-hearth and other regenerative furnaces.

In some locations it is necessary to use two-pass checkerworks because of height or depth limitations. However, these are troublesome because the necessary limitation in cross-sectional area of each pass causes the first pass to be overworked due to slagging or soot deposits, which in turn causes burning out and erosion of the refractories. One of the chief causes of this condition lies in the lack of suitable means to remove solids entrained in the hot gases discharged from the furnace.

In the present invention, this situation is remedied by providing an auxiliary slag pocket below the first pass, and passing the gas up through the first pass after it has been more or less cleaned through dropping its solids in the slag pocket.

As shown in Figure 1, the checkerwork 3 has a partition wall of dividing it into two passes 5 and 6. The checkerwork is supported on arches 9 above the floor. Thus, underlying chambers 10 and 11 are provided which are respectively connected to the furnace and to the stack. The port 10 forms a slag chamber, which contains a series of slag and dust pockets 11a in which conveyors 12 are mounted for withdrawing the deposited material. Air, fluid, or liquid jets 13 may also be added.

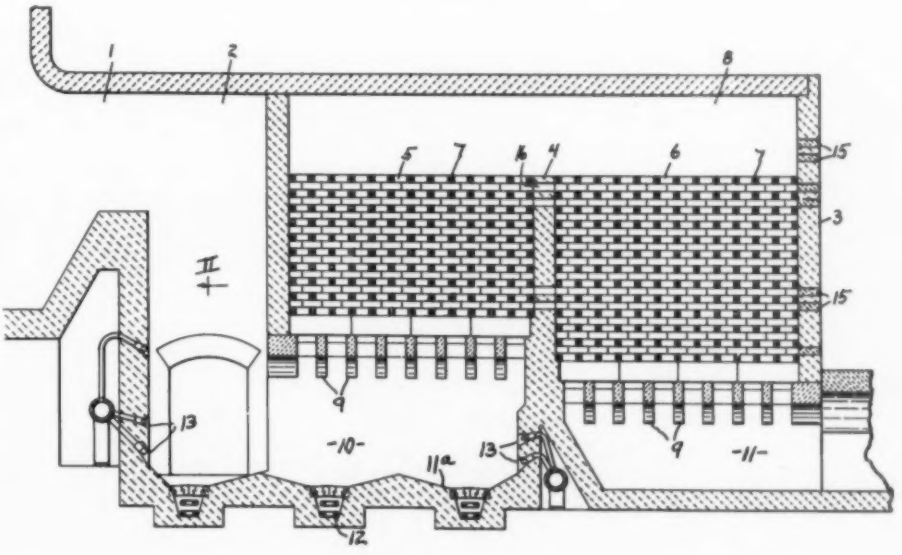
Means are provided for cleaning the checkerwork through openings 15 in one end wall of the chamber, alined with openings 16 in the partition 4.

METHOD OF FORMING AN INSULATING COATING ON STEEL

▲ U.S. 2,753,282, issued July 3, 1956 to Paul E. Perry and assigned to Allegheny Ludlum Steel Corp., provides an insulating coating for steel used for electrical applications.

In addition to providing good insulating qualities, the coating has a minimum of dusting tendencies, does not decompose under heat up to 1600 F. and has good lubricating properties during stamping operations. Three basic ingredients are used, chromic acid, monobasic ammonium phosphate, and primary magnesium

Figure 1



phosphate, as a water soluble solution film. This solution may be applied by spraying, dipping, or rolling, and after its application the phosphating is effected by baking at 800 to 1000 F.

SPECIAL FUEL OIL FOR OPEN HEARTH FURNACES

▲ U.S. 2,754,198, issued July 10, 1956 to Ernest S. Starkman and Stanley S. Soren, assigned to Shell Development Co., describes a special fuel oil for use in open hearth furnaces, in order to minimize carbon and soot deposition on the surfaces of the checkerwork.

It has been known for some time that carbon and soot deposition can be eliminated by incorporating small amounts of sodium or calcium naphthenates into the fuel. However, these have a deleterious effect on the acidic refractories used in the furnace.

Another problem with the use of fuel oil in the open hearth has been the increasingly high sulfur content of residual fuel oils.

The patent, however, indicates that the presence of both sulfur and sodium or calcium naphthenates "neutralizes" the adverse effects of each. The relative quantities of each are critical, i.e.

$$S = \frac{16.2\ AM}{m} + 0.99 \pm 0.40$$

where S and M are the weight per cent of sulfur and alkaline metal, respectively, based on the quantity of fuel burned, A is the hydrogen equivalent of the alkaline metal, and m is the molecular weight of the alkaline metal.

METHOD OF DESCALING STEEL

▲ U.S. 2,757,107, issued July 31, 1956 to James J. Heger and Michael A. Orehoski, assigned to United States Steel Corp., provides a method for descaling steel to be hot-worked.

The inventors state that the scale formed on steel masses during or after heating preparatory to hot-working may be easily removed or converted to a non-injurious condition by immersion in a bath of molten slag. The slag may be that formed naturally in smelting iron ore or may be a synthetic product consisting of a mixture of two or more metal oxides. Such a bath has the effect of dissolving the scale forming on heated masses of steel or rendering it soft enough to be readily detached by hot-working tools without injury to the steel or to the surface of the wrought masses. It is preferable to add to the slag a flux capable of lowering its melting point and increasing its fluidity.

As shown in Figure 2, the slag-flux ratio may vary between 20 to 80 and 93 to 7. The analyses of these five slags is given in Table I.

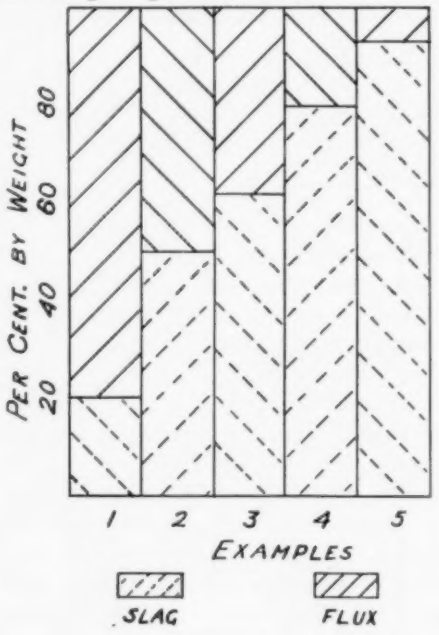


Figure 2

Molten slag baths of the compositions given for Examples 1 and 2 were quite fluid above 1800 F and were effective rapidly to descale both carbon and stainless steel when heated bars were immersed in the baths. Baths of compositions 3, 4, and 5 also effectively descaled heated bars of carbon and stainless steel, but their action was slower.

PRODUCTION OF MAGNESIUM CONTAINING CAST IRON

▲ U.S. 2,757,082, issued July 31, 1956 to Arthur D. Busby and Ronald H. T. Dixon, assigned to The International Nickel Co., Inc., describes a new magnesium — containing addition agent for producing cast iron containing spheroidal graphite, which avoids loss of magnesium by violent reaction.

It is known that magnesium nitride does not react violently with cast iron, but it does not decompose rapidly enough to introduce a sufficient amount of magnesium into the melt to insure the development of spheroidal graphite. However, since magnesium nitride is rich in magnesium and contains no other metal, it is attractive as an addition agent.

It has now been discovered that a promoter may be added to the magnesium nitride in order to avoid this difficulty. The promoter may be metallic magnesium, silicon, or carbon. Small lumps of ferrosolicon, from ⅛ to ½ in. in size, are preferred as the promoter. Graphite is also a very good promoter, preferably ¼ to ⅛ in. in size.

TREATING IRON OR MILD STEEL TO PROMOTE ADHERENCE OF PORCELAIN ENAMEL

▲ U.S. 2,755,210, issued July 17, 1956 to Fred G. Sutphen, Jesse J. Canfield, Robert L. Myers, Joseph E. Sams, and Robert S. Burns, assigned to Armco Steel Corp., provides a process of treatment for promoting the adherence of porcelain enamels to ferrous metals.

The process involves the following three steps: (1) The surface of the

TABLE I

	Percentage components by weight				
	Example 1	Example 2	Example 3	Example 4	Example 5
Slag-components:					
Lime	5	25	33	40	..
Silica	15	25	..	40	3
Alumina	..	..	33	..	..
Blast-furnace slag	..	..	..	..	90
	20	50	66	80	93
Flux-components:					
Fluorspar	..	25	17	10	..
Cryolite	..	25	17	10	..
Borax	50	..	..	..	7
Soda Ash	30	..	..	..	..
	80	50	34	20	7

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ferrous metal sheet stock or article is coated with a thin layer of cobalt or nickel, e.g. by electroplating. (2) The treated stock is scaled, i.e., oxidized by heating it in an atmosphere which is oxidizing and non-carburizing to iron. This appears to alloy at least a part of the coating metal with the iron. (3) The scaling is followed by an acid pickle.

It is found that the scaling anneal makes possible the production of a desirable type of roughness in the pickling step, leading to greatly enhanced adherence.

RECOVERY OF VALUES FROM ORES CONTAINING IRON AND NICKEL

▲ U.S. 2,757,077, issued July 31, 1956 to Reed Lewis, Jack W. Cookston, and L. Wallace Coffer, assigned to Crucible Steel Co. of America, describes a process for treating nickel-bearing lateritic iron ores to recover and separate metal values from it.

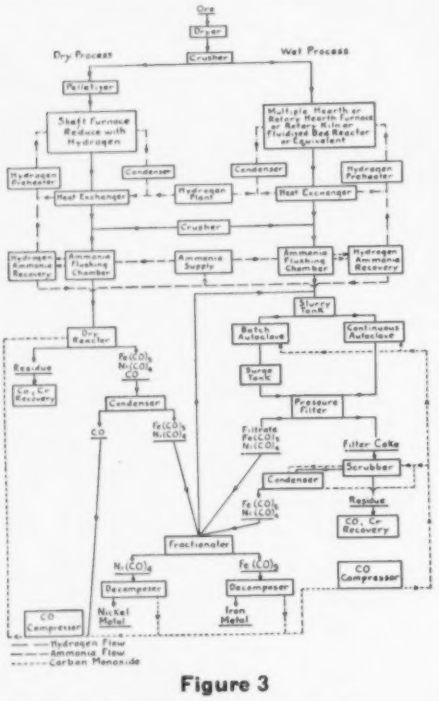


Figure 3

The process is shown schematically in Figure 3.

PRODUCTION OF ALLOYS

▲ U.S. 2,757,083, issued July 31, 1956 to Edward B. Story and assigned to A. M. Byers Co., describes a method of making a metal alloy, employing a compound of an alloying metal to be alloyed with basis metal, and basis metal which is reducing toward the compound.

Thus, iron ores found in Cuba and elsewhere contain small percentages of nickel, e.g. 1 to 2 per cent. Such an ore is charged to a rotary melting furnace, and brought to a molten condition at 2300 to 2400 F, the melt consisting of iron silicate slag containing nickel oxide. Carbon is also added during the melting step, to reduce most of the ferric oxide to ferrous oxide. The melting point of the slag is about 2300 F.

Molten ferrous metal, such as pig iron or partly refined iron, is separately prepared. Assuming the carbon content of the metal to be 0.10 to 0.15 per cent, its melting point will be about 2750 F, and the molten metal will be brought to 2900 to 3000 F.

The molten slag is placed in the bottom of a receptacle, into which the molten metal is poured. The amount of slag in the receptacle may, for example, be 50,000 lb, and the amount of ferrous metal 7500 lb. The iron is thus transformed into a mass of small particles, thus presenting great surface area to the molten slag, for effective reduction of the nickel oxide. The nickel in metallic form thus deposits on the particles of ferrous metal, and the slag is poured off. The product is then a non-homogeneous alloy consisting largely of minute particles of iron covered with nickel.

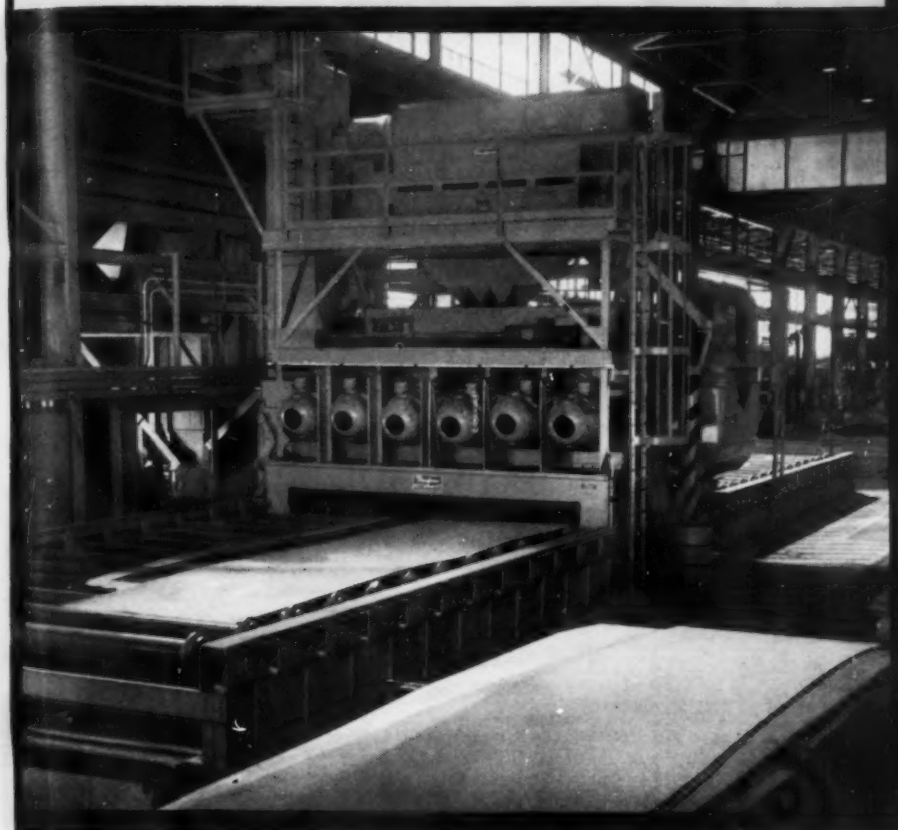
The method is thus somewhat similar to the Aston process of making wrought iron.

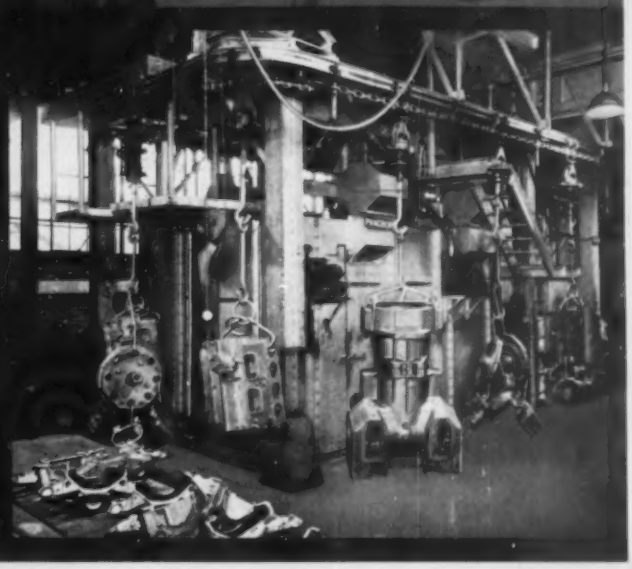
The product may, if desired, be employed in a steelmaking process to produce alloy steel.

OTHER PATENTS OF INTEREST TO THE IRON AND STEEL ENGINEER

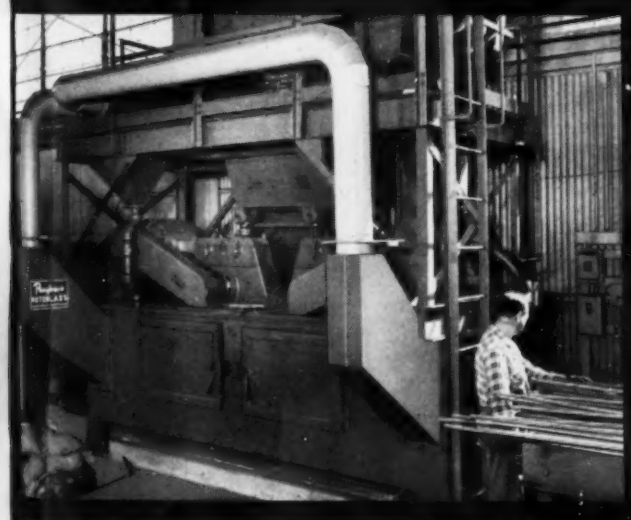
Patent No.	Date	Subject	Inventor or Assignee
2,752,803	7/ 3/56	Electrical power system for steel rolling mills	Lukens Steel Co.
2,752,804	7/ 3/56	Metal rolling mills	Mesta Machine Co.
2,752,873	7/ 3/56	Apparatus for feeding and forming sheet strip stock into a helix	Armco Steel Co.
2,753,171	7/ 3/56	Open hearth steel furnace	General Refractories Co.
2,753,200	7/ 3/56	Apparatus for unfastening spring latched coke oven doors	Koppers Co.
2,753,260	7/ 3/56	High silicon-carbon tool steel	Crucible Steel Co. of America
2,753,464	7/ 3/56	Apparatus for inspecting tinplate	Republic Steel Corp.
2,753,605	7/10/56	Apparatus for metering of molten metal by weight	Republic Steel Corp.
2,753,612	7/10/56	Forming magnesia refractory furnace bottoms	Bethlehem Steel Co.
2,753,949	7/10/56	Benzol spray scrubber	Otto Construction Corp.
2,754,104	7/10/56	Apparatus for heating ingots	Selas Corp. of America
2,754,105	7/10/56	Smelting apparatus for iron ores, using briquettes of coal and ore	Otto Pistorius and Ludwig Weber
2,754,172	7/10/56	Manufacturing ferromagnetic material	Hartford National Bank & Trust Co.
2,754,174	7/10/56	Treatment of salt solutions to remove iron	Bethlehem Steel Co.
2,754,193-5	7/10/56	Process for making copper-iron powder	Republic Steel Corp.
2,754,197	7/10/56	Rotary kiln for the manufacture of sponge iron	Fritz Otto Wienert
2,754,201	7/10/56	Alloying magnesium with cast iron	The International Nickel Co., Inc.
2,754,222	7/10/56	Preparation of steel for glassing	A. O. Smith Corp.
2,754,981	7/17/56	Side charged horizontal coke oven	Koppers Co., Inc.
2,755,031	7/17/56	Coiler drum for strip material	Davy & United Engineering Co., Ltd.
2,755,180	7/17/56	Reverberatory furnace practice	Carl G. de Laval, Jr.
2,755,181	7/17/56	Introduction of boron into ferrous metal	Societe Anonyme pour l'Etude et l'Exploitation des Procedes Georges Claude
2,755,192	7/17/56	Mold coat	General Motors Corp.
2,756,137	7/24/56	Direct production of iron and steel from ores	Friedrich Kocks
2,756,169	7/24/56	Heat treating hot rolled steel rods	John A. Roebling's Sons Corp.
2,756,198	7/24/56	Low temperature tar conversion to high temperature tar in high temperature coking chambers	Koppers Co., Inc.
2,756,701	7/31/56	Soaking pit coping	M. H. Detrick Co.
2,756,783	7/31/56	Wire-tying machine	United States Steel Corp.
2,756,942-3	7/31/56	Apparatus for coiling strip material	United Engineering & Foundry Co.
2,756,986	7/31/56	Roasting sulphide ores	Metallgesellschaft Aktiengesellschaft
2,756,988	7/31/56	Transfer device for conveying molten metal	Ajax Engineering Corp.

If you have





an unusual blast cleaning problem,



If you are a company with a special cleaning problem, Pangborn offers you a special service—a machine designed for your individual needs. It might be a descaling machine for bars, sheets and coils, a continuous-flow barrel or a monorail cabinet like the machines shown here . . . or it might be completely different. You may need to clean cylinder blocks, bathtubs or any unusual ferrous or nonferrous castings, forgings, stampings. If so, Pangborn engineers will study your problem and its relation to your production line. Then they'll design a Pangborn machine that gives you better cleaning and faster production at lower cost. Pangborn has proved it in hundreds of cases. Pangborn can prove it to you! Write today for Bulletin 1210 to: PANGBORN CORP., 4400 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

*U. S. Pat. #2184926 (other patents pending)

Pangborn Rotoblast® can solve it!

Pangborn

BLAST CLEANS CHEAPER

Rotoblast Blastmaster® & Continuous-Flo Barrel

Rotoblast Tables & Table-Rooms

Special Blast Rooms & Cabinets

Pangborn Dust Control Equipment

Distributors for Mallenbrandus and Tru-Steel Abrasives

Pace-setting records

48" Continuous Galvanizing Line

October 1, 1954

ENGINEERING BEGAN

December 26, 1954

CONSTRUCTION BEGAN

June 10, 1955

PRODUCTION BEGAN

48" Electrolytic Tinning Line

January 7, 1956

ENGINEERING BEGAN

March 20, 1956

CONSTRUCTION BEGAN

August 10, 1956

PRODUCTION BEGAN

ELECTRICAL INSTALLATIONS
PATTERSON EMERSON COMSTOCK, INC.
PITTSBURGH, PA.

PATTERSON-EMERSON-COMSTOCK, INC.
PATTERSON-EMERSON-COMSTOCK INTERNATIONAL, INC.
313 E. Carson Street, Pittsburgh 19, Pa.

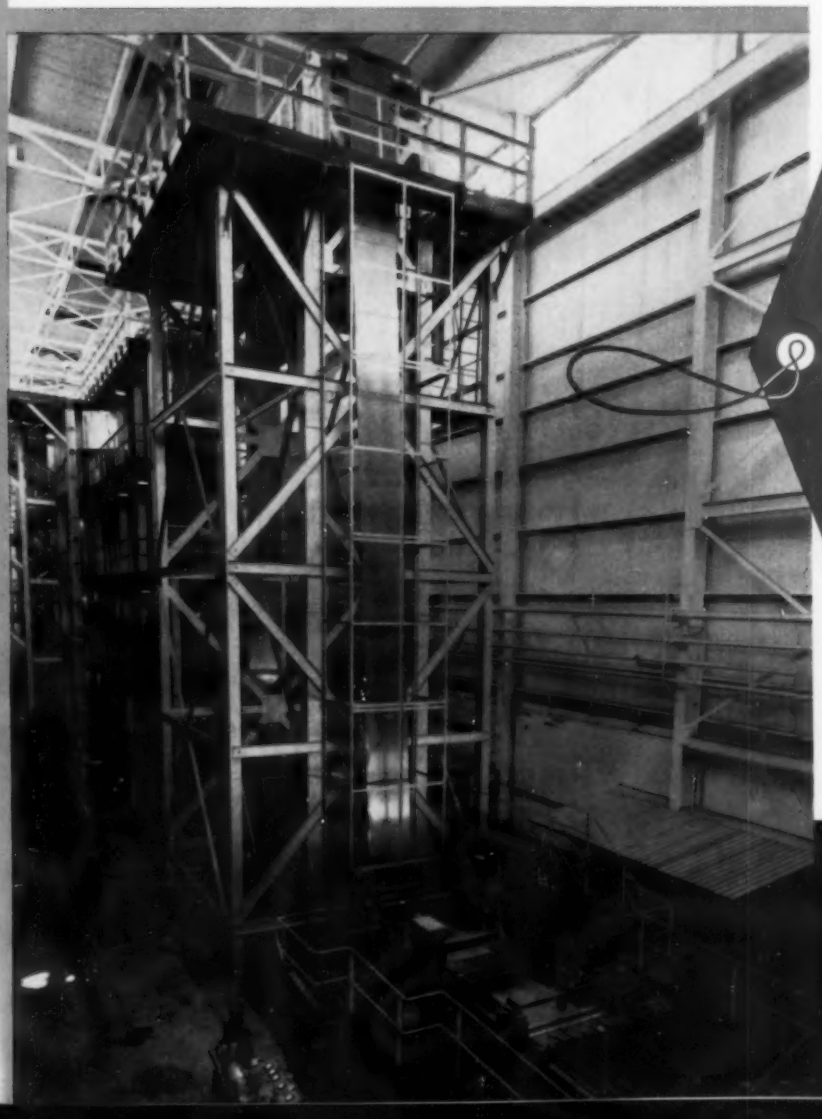
feature construction at DOFASCO

Dofasco

Realistic teamwork permits the pace-setting records accomplished in the engineering and construction of the expansion program at Dofasco—The Dominion Foundries and Steel Co., Ltd. of Hamilton Ontario, Canada.

The team includes: The Dofasco organization under the direction of Mr. D. O. Davis, Vice President of Engineering for Dofasco; and Patterson-Emerson-Comstock which is furnishing the complete construction engineering, and in joint venture with H. K. Ferguson of Canada has completed construction of the facilities illustrated on the record-making schedules shown.

In addition, Patterson-Emerson-Comstock has participated as engineers or constructors on other Dofasco projects including: #2 Blast Furnace, "C" Furnace Oxygen Converter Installation, three Shear Lines, 56" Temper Mill, Reversing Slabbing Mill, 56" Reversing Cold Mill and 60" Continuous Pickling Line.



48" Tower Annealing Line

November 17, 1955
ENGINEERING BEGAN

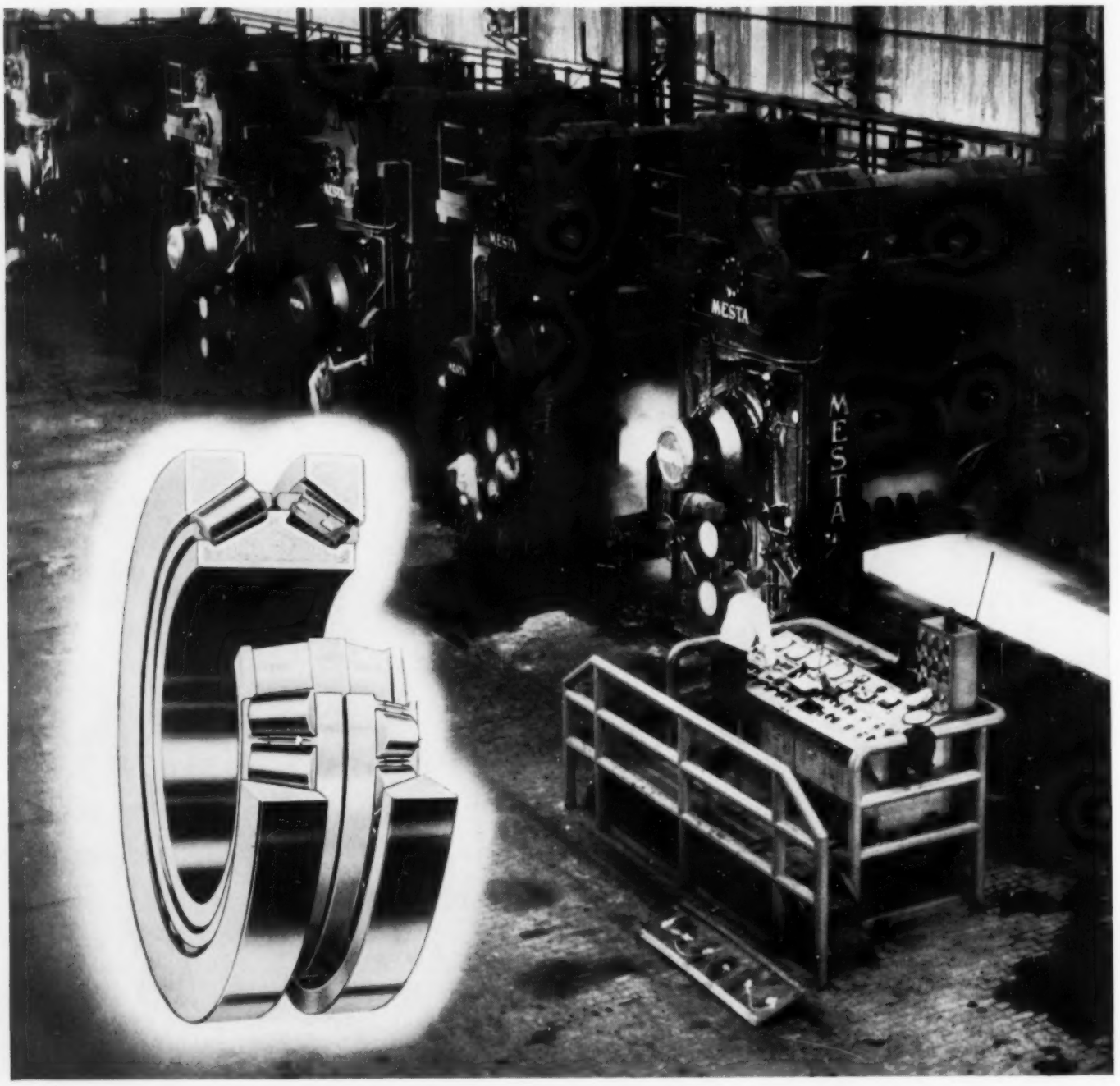
November 24, 1955
CONSTRUCTION BEGAN

July 19, 1956
PRODUCTION BEGAN

ELECTRICAL INSTALLATIONS
PATTERSON EMERSON COMSTOCK, INC.
PITTSBURGH, PA.

- Hamilton, Ont., Canada
- Pittsburgh, Penna.
- New York, N. Y.
- Warren, Ohio
- Portsmouth, Ohio
- Birmingham, Ala.
- San Francisco, Calif.
- Los Angeles, Calif.

TORRINGTON *STEEP-ANGLE* TAPERED ROLLER BEARINGS



. . . your best investment on back-up rolls!

Rolling record tonnages of steel calls for back-up roll thrust bearings that can stand up under repeated shock and stress in continuous service. Torrington's steep-angle construction for thrust bearings assures maximum capacity and service life.

One-piece, cast-bronze cages, with machined pads in each roller pocket, give accurate roller guidance and effective lubrication. Only the finest quality electric furnace alloy steel is used in the manufacture of Torrington bearings, carefully heat treated to provide hardness and toughness.

Specify Torrington's Steep-Angle Two-Row Tapered Roller Bearings for your back-up thrust application. In tons handled, down time saved, you'll agree they're your best investment. Many sizes are available for immediate shipment.

THE TORRINGTON COMPANY
South Bend 21, Ind. • Torrington, Conn.
District offices and distributors in principal cities of United States and Canada

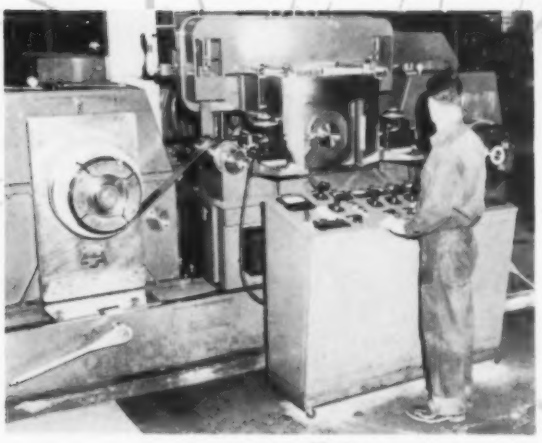
90th ANNIVERSARY 1866–1956

TORRINGTON BEARINGS

Tapered Roller • Spherical Roller • Cylindrical Roller
Needle • Ball • Needle Rollers

RELIANCE V★S DRIVE®

TAKES ANY QUESTION OUT OF SPECIALTY METAL ROLLING



Top quality specialty-metal for pressure gauges, instrument springs, diaphragms, and other devices is rolled on this highly flexible Sendizimir mill at Beryllium Corporation.

Roughing, breakdown and finish passes are made with precision control, all on one mill, at speeds from 0-400 fpm. Small coils are used to eliminate intermediate annealing.

A Reliance V★S Drive takes any question out of this type of manufacturing . . . by providing close control of tension, variable speed for all gauges, smooth acceleration and deceleration, dynamic braking, and other features. All guess work is eliminated, with improved quality!

Reliance V★S Drives are solving difficult industrial problems everywhere. What's *your* drive problem?

Write for Bulletin D-2311. D-1514

RELIANCE ELECTRIC AND ENGINEERING CO.

DEPT. 1112A, CLEVELAND 10, OHIO • CANADIAN DIVISION: WELLAND, ONTARIO

Sales Offices and Distributors in Principal Cities

HAGAN CONTROL helps

Flexibility of Hagan control system permits solution of ingot heating problem at Crucible Steel's Midland Plant.

Faced with the need for better circulation at low fuel input, Crucible's engineers adjusted the Hagan Fuel-Air regulator so that it was biased to produce automatically an accurately measured dilution of the gas-air mixture at low flows (from 106% theoretical air during the heating period to 215% theoretical air during the soaking period). No scale problem was encountered.

This gave the effect of firing a low Btu gas and achieved the desired uniformity of heat distribution. Tons per hour increased, and Btu's per ton decreased.

The engineers were very satisfied with the results achieved by this change, and made the comment, "We were fortunate in having a control flexible enough to do this."

Hagan control components are built with this particular objective in mind. Every unit is designed to offer engineers wide latitude not only in application, but also in performance. Hagan instruments and controls are dependable, extremely accurate and versatile. Why not discuss your control and instrumentation problems with the Hagan engineer. He can help you find a solution.

solve a soaking pit problem

NOTES ON THE HAGAN INSTALLATION AT CRUCIBLE STEEL'S MIDLAND PLANT.

Fuel-Air Ratio Control

A high degree of accuracy is achieved in this part of the Hagan soaking pit control. In normal operation, a double diaphragm regulator controls the ratio by pneumatically repositioning the combustion air valve. This normal operation can be varied by moving the fulcrum of the ratio regulator. This is provided by:

Combustion Air Temperature Compensation

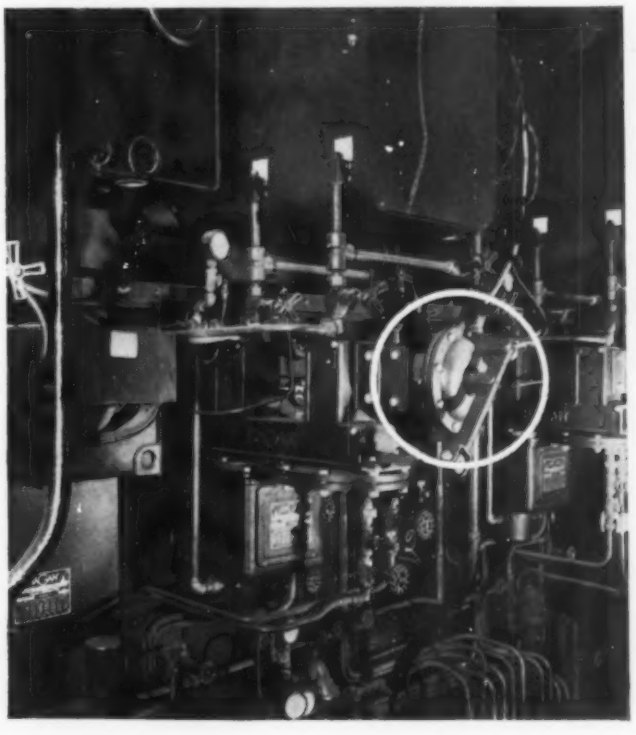
By means of an air temperature transmitter, connected to a thermocouple in the hot air duct, a pneumatic signal is transmitted to a diaphragm operator. This operator serves as a fulcrum positioner for the fuel-air ratio regulator, so that the ratio is maintained despite variations in combustion air temperature.

Hagan control systems are also used for collector flue draft control, pit pressure measurement, recuperator temperature control and measurement and for the safety systems. These various parts of the overall system are functioning accurately and dependably, and actual records show extremely low maintenance costs. To quote the Crucible engineers again, "Considering the types of steel being heated, controlled-heating cycles required, and track times, we believe the pits are doing an excellent job."

Reprints of an article, "Problems of a New Soaking Pit Installation" are available. Write for your copy.

Control panel for Crucible Soaking Pits.

Back of panel, showing double diaphragm fuel-air ratio control and (in circle) the temperature compensating fulcrum positioner.



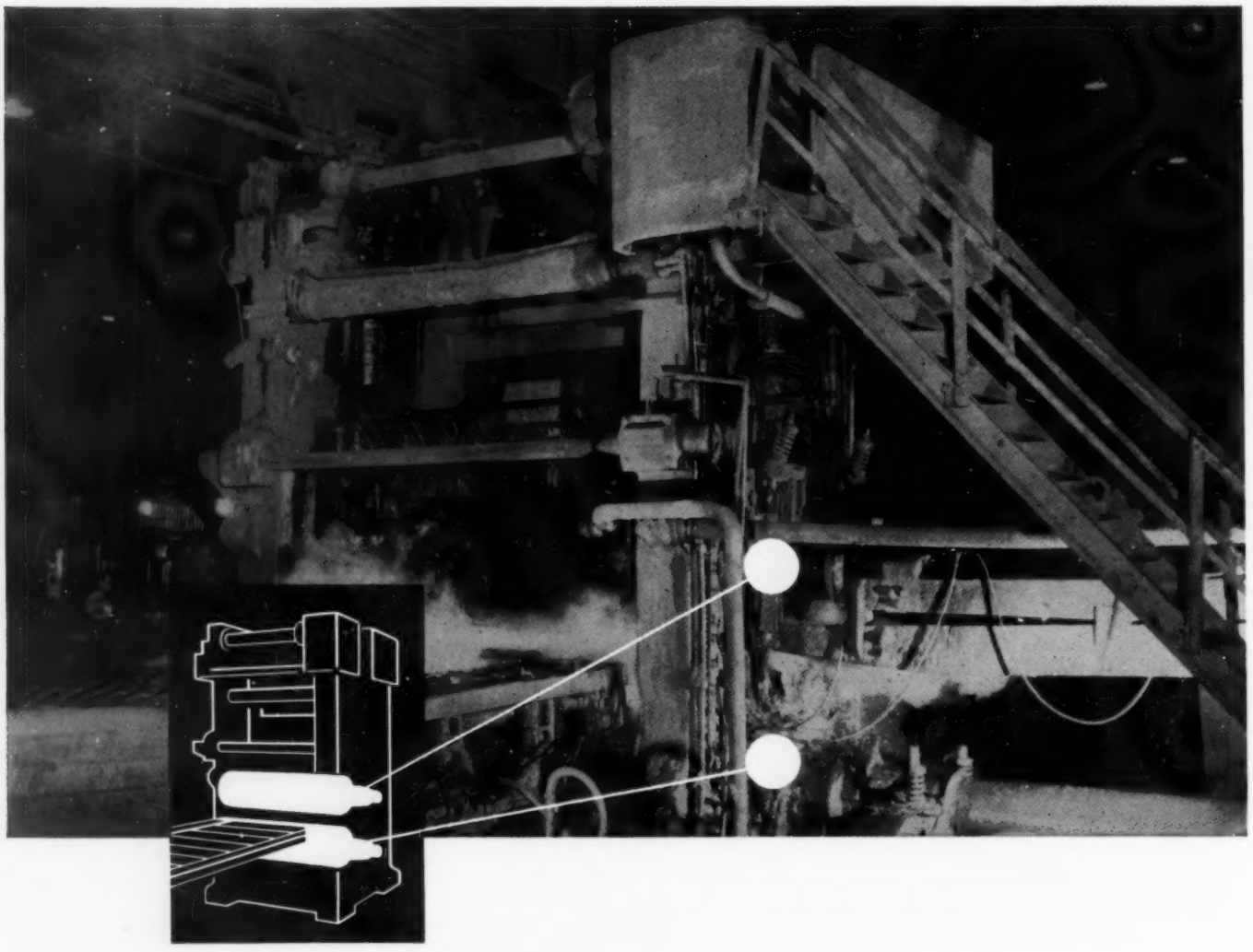
HAGAN CORPORATION

HAGAN BUILDING, PITTSBURGH 30, PA.

Systems and Components for: Metallurgical Furnace Control, Boiler Combustion Control, Process Control, Aeronautical Testing Facilities • Industrial Water Treatment • Chemicals for Water Conditioning

HAGAN SUBSIDIARIES: CALGON, INC. • HALL LABORATORIES, INC.

Lubricating roll necks is no easy job



Lubricating the roll necks of a steel mill calls for a lubricant that will resist high temperatures. The lubricant must also function in the presence of steam, water, mill scale and other abrasive materials. It has to cushion great shock loads and cling tenaciously to the bearings it protects. It must last a long time . . . and it must be economical in use.

Atlantic Lubricant 10 performs exceptionally well in this service. It is being used in a pressure system on the mill illustrated, at the Lukens Steel Company in Coatesville, Pa., for the lubrication of roll neck bearings, pinion and spindle bearings.

Selecting the correct lubricant for the job is simplified when you call in your Atlantic Lubrication Engineer. He is a man with years of on-the-job knowledge of heavy industrial lubrication requirements of all kinds.

Why not see for yourself the value of Atlantic service? Just write, wire or phone the office nearest you for full information. The Atlantic Refining Company, Dept. V-12, 260 South Broad Street, Philadelphia 1, Pa.

PROVIDENCE, R. I.
430 Hospital Trust Bldg.

SYRACUSE, N. Y.
Salina and Genesee Sts.

READING, PA.
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PITTSBURGH, PA.
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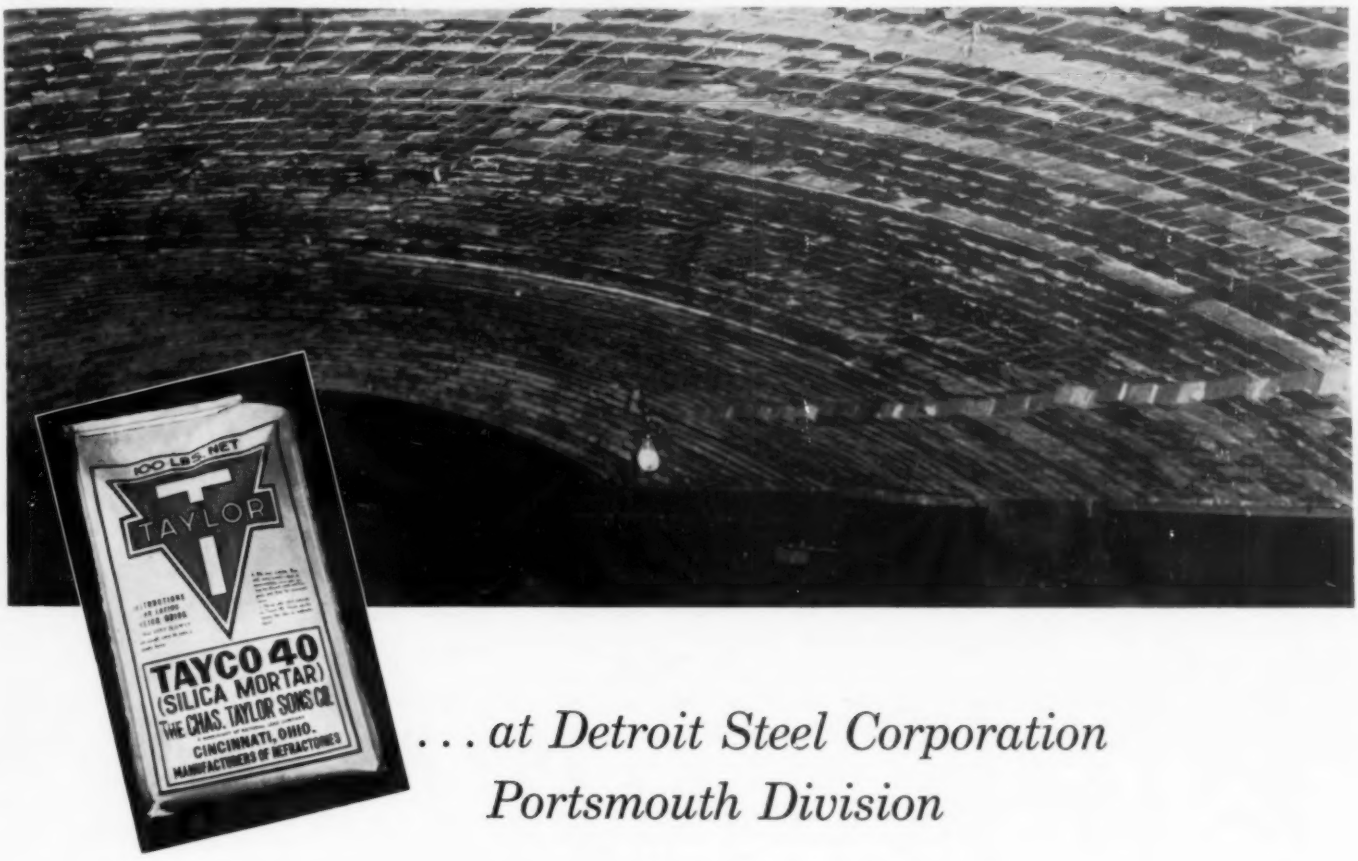
CHARLOTTE, N. C.
1112 South Boulevard

ATLANTIC

LUBRICANTS · WAXES
PROCESS PRODUCTS

Tayco 40 BONDS THE ROOFS...

Photograph courtesy of Detroit Steel Corporation



. . . at Detroit Steel Corporation Portsmouth Division

The Portsmouth Division, Detroit Steel Corporation—as well as other leading steel mills in the United States—is using Tayco-40 High Temperature Silica Cement to improve the life of silica open hearth furnace roofs.

Tayco-40 is nearly as refractory as the best grades of silica or super-duty silica brick. Because of its superior water-retention properties, Tayco-40 is smooth working—remains plastic longer—making it easy to lay brick with thin, tight joints. These properties are obtained without the addition of plastic fire clays found in most silica cements.

If your open hearth shop has not yet tried Tayco-40, see the Taylor field engineer in your district or write direct for a sample and copy of Bulletin No. 507.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

TAYLOR ZIRCON
TAYLOR SILLIMANITE

The CHAS. TAYLOR SONS Co.
A SUBSIDIARY OF NATIONAL LEAD COMPANY
REG. U. S. PAT. OFF.
REFRACTORIES SINCE 1864 • CINCINNATI • OHIO • U. S. A.

FURNACES

FOR EVERY INDUSTRIAL HEAT TREATING PROCESS

We specialize in designing and building production furnaces; special atmosphere generators; time and labor saving material handling and other auxiliary equipment.

EF

Fuel Fired and Electric Furnaces for processing strip, wire, tubing, stampings, castings, forgings and other ferrous and nonferrous products in any shape or form.

1957

JANUARY

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1957

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The Electric Furnace Co., Salem, Ohio

Gas Fired, Oil Fired and Electric Furnaces---For Any Process, Product or Production

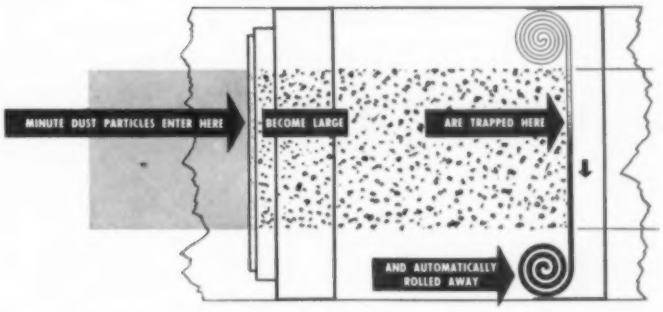
Here's how to eliminate scheduled air filter maintenance!

This free booklet gives the facts about the new air filtration unit that eliminates scheduled filter maintenance!

AAF's ROLLOTRON offers the ultimate in efficiency—electronically clean air. Fine dust particles adhere to each other on the dry plates of ROLLOTRON'S precipitator section. When the build-up becomes great enough, the accumulation is carried by the air stream onto the automatically-renewing media of the storage section.

There's virtually no maintenance on the precipitator section, and the only maintenance on the storage section is the replacement of a dirt-laden roll of media with a new roll . . . an operation as simple as changing the film in your camera. Send the coupon for new ROLLOTRON Bulletin. Do it now, while you're thinking of it.

SEND FOR THIS *Free* BOOKLET



AAF herman nelson

American Air Filter
COMPANY, INC.

302 Central Avenue, Louisville 8, Kentucky
American Air Filter of Canada, Ltd., Montreal, P. Q.

American Air Filter Company, Inc.
302 Central Avenue, Louisville, Ky.

Please send me ROLLOTRON Bulletin 249, which gives complete information on this new air filtration unit.

Name_____

Company_____

City_____ State_____

GENERAL ELECTRIC ANNOUNCES

static switching systems

General Electric's new static switching systems have been designed to increase significantly the dependability and life of control equipment where frequent operations, complex systems, and continuous processes are required or atmospheric problems exist.

These new G-E systems utilize static-magnetic and solid-state devices to perform a variety of control functions normally accomplished by contact-making devices. Static switching systems consist of varied combinations of seven basic units: an isolation switch unit, two multi-purpose units, a long time-delay unit, a short time-delay unit, an "AND" unit, and an "OR" unit. These units can also be combined with static power supplies, static amplifiers, and static regulators to provide completely static control systems.

Where frequent operations are involved, static switching systems are ideal, as they have no moving parts to wear.

Where complex control functions are required, the simplified circuitry of the static switching systems makes them particularly applicable.

For continuous processes, these systems assure dependability through the use of pre-tested, industry-proved static components.

Unaffected by most atmospheric conditions, the static units are encapsulated in an inert, lightweight compound.

General Electric control engineers are ready now to help you apply the benefits of static switching systems to your machines or processes. For additional information, contact your nearest General Electric Apparatus Sales Office, or write for Bulletin GEA-6364 to Sect. 785-2, General Electric Co., Schenectady 5, New York. *Industry Control Dept., Roanoke, Virginia.*

Progress Is Our Most Important Product

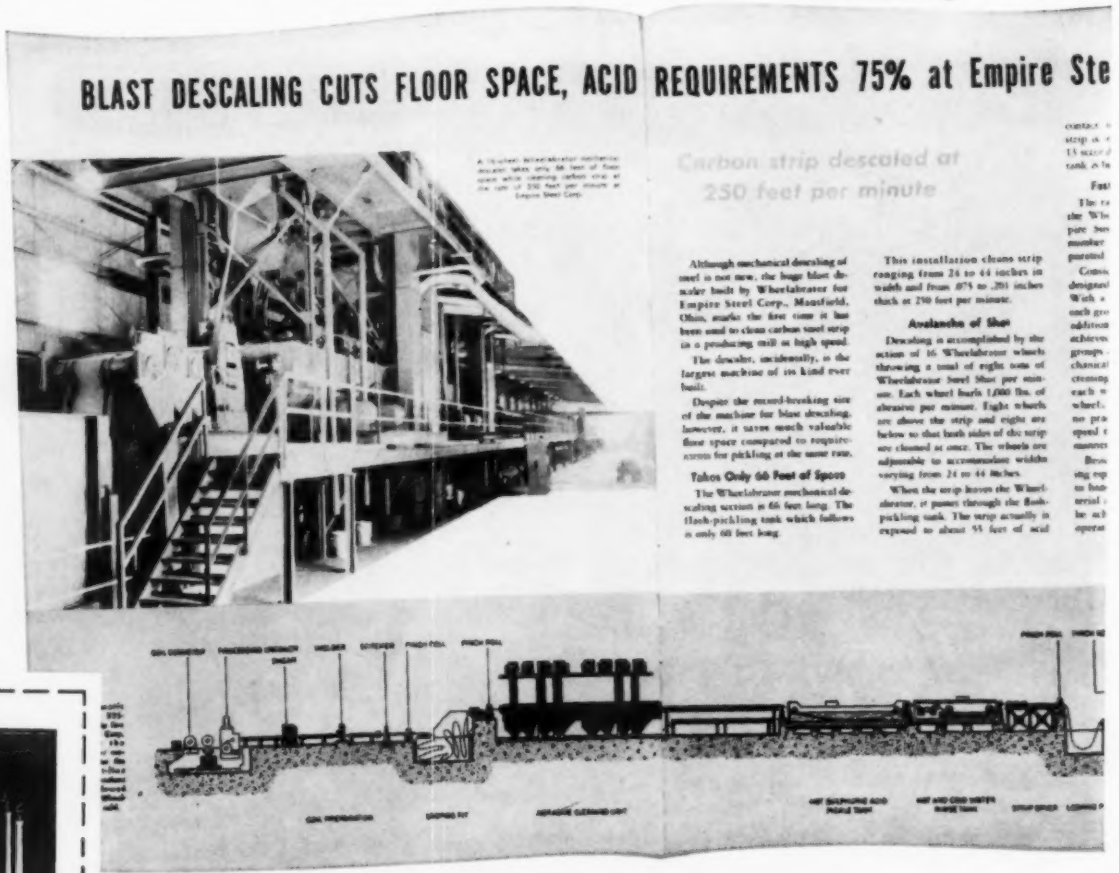
GENERAL ELECTRIC

CAT. NO.

profit from Wheelabrator® savings

descaling strip and sheet steel

Steel producers and processors are rapidly discovering how Wheelabrator Mechanical Descaling brings savings in time, labor, space and material and results in improved final products. In many installations, mechanical descaling requires only ¼ as much space as acid pickling. In others, labor requirements are reduced as much as 50%. In still others, Wheelabrating saves not only cleaning time but speeds production by permitting straight-line operation not possible with acid pickling. In addition, Wheelabrating removes no virgin metal, thus saving metal. And elimination or reduction of acid pickling saves on acid requirements and minimizes acid disposal problems and expense. While making all these savings, Wheelabrating also provides a matte finish that has proved superior for cold working.


BLAST DESCALING CUTS FLOOR SPACE, ACID REQUIREMENTS 75% at Empire Ste

Carbon strip descaled at 250 feet per minute

Although mechanical descaling of steel is not new, the huge blast descaler built by Wheelabrator for Empire Steel Corp., Mansfield, Ohio, marks the first time it has been used to clean carbon steel strip in a producing mill at high speed.

The descaler, incidentally, is the largest machine of its kind ever built.

Despite the record-breaking size of the machine for blast descaling, however, it saves much valuable floor space compared to equipment for pickling at the same rate.

Takes Only 60 Feet of Space

The Wheelabrator mechanical descaling section is 66 feet long. The flash-pickling tank which follows is only 60 feet long.

This installation cleans strip ranging from 24 to 44 inches in width and from .075 to .250 inches thick at 250 feet per minute.

Avalanche of Shot

Descaling is accomplished by the action of 16 Wheelabrator wheels throwing a total of eight tons of Wheelabrator Steel Shot per minute. Each wheel hurls 1,000 lbs. of abrasive per minute. Eight wheels are above the strip and eight are below so that both sides of the strip are cleaned at once. The wheels are adjustable to accommodate widths varying from 24 to 44 inches.

When the strip leaves the Wheelabrator, it passes through the flash-pickling tank. The strip actually is exposed to about 55 feet of acid

FOR SPECIFIC EXAMPLES OF SAVINGS send today for your free copy of Bulletin 128-D. Actual case histories of Wheelabrator installations show how savings are achieved. Shown above is a report in this highly-informative, thoroughly-illustrated 8-page bulletin.

WHEELABRATOR
CORPORATION

396 South Byrkit Street Mishawaka, Indiana

Catenary Furnaces

A 12,000 lbs/hour Fuel-fired Catenary Annealing Furnace for stainless strip used in line with spray quench followed by descaling and pickling baths.

FURNACE CHARACTERISTICS

Inside Dimensions 50'-0" long x 7'-0" wide x 6'-8 3/8" high

Fuel Input ..... 1,800,000 BTU/hour

Operating Temperature Range . . 1200 to 2250°F

Stainless Strip . . . . . Cold reduced—annealed in gauges from 0.007" to 0.125"

Stainless Strip . . . . . Hot rolled—annealed in gauges from 0.093" to 0.200"

Three (3) zone proportioning control

Complete control over fuel-air ratio to maintain desired atmosphere in furnace

DREVER COMPANY

RED LION RD. & PHILMONT AVE., BETHAYRES, PA.

23

New spindle design for Farrel® HD grinder! Result: *finer accuracy, reduced maintenance*

A number of improvements have recently been made in the Farrel heavy duty roll grinder and important among these is the new grinding wheel spindle design.

Of large diameter for its length—to assure rigidity under working load—the spindle is mounted in Farrel "Truaxial" bearings. These offer many benefits over previous designs for smooth, vibrationless operation, faster and better finishing, ease of adjustment, positive lubrication and economy of maintenance.

Split, self-aligning pillow blocks provide positive positioning of the spindle in its bearings. Adjustment of running clearance is accomplished through adjusting screws. Contracting pressure of the pillow block on the supporting points of the bearing creates the effect of five individual bearing shoes, with a self-energized, high-pressure wedge of oil entering each of the five bearing areas. A fresh supply of oil is introduced between each of the bearing areas under predetermined pressure to assure an adequate, unbroken film over the entire bearing surface.

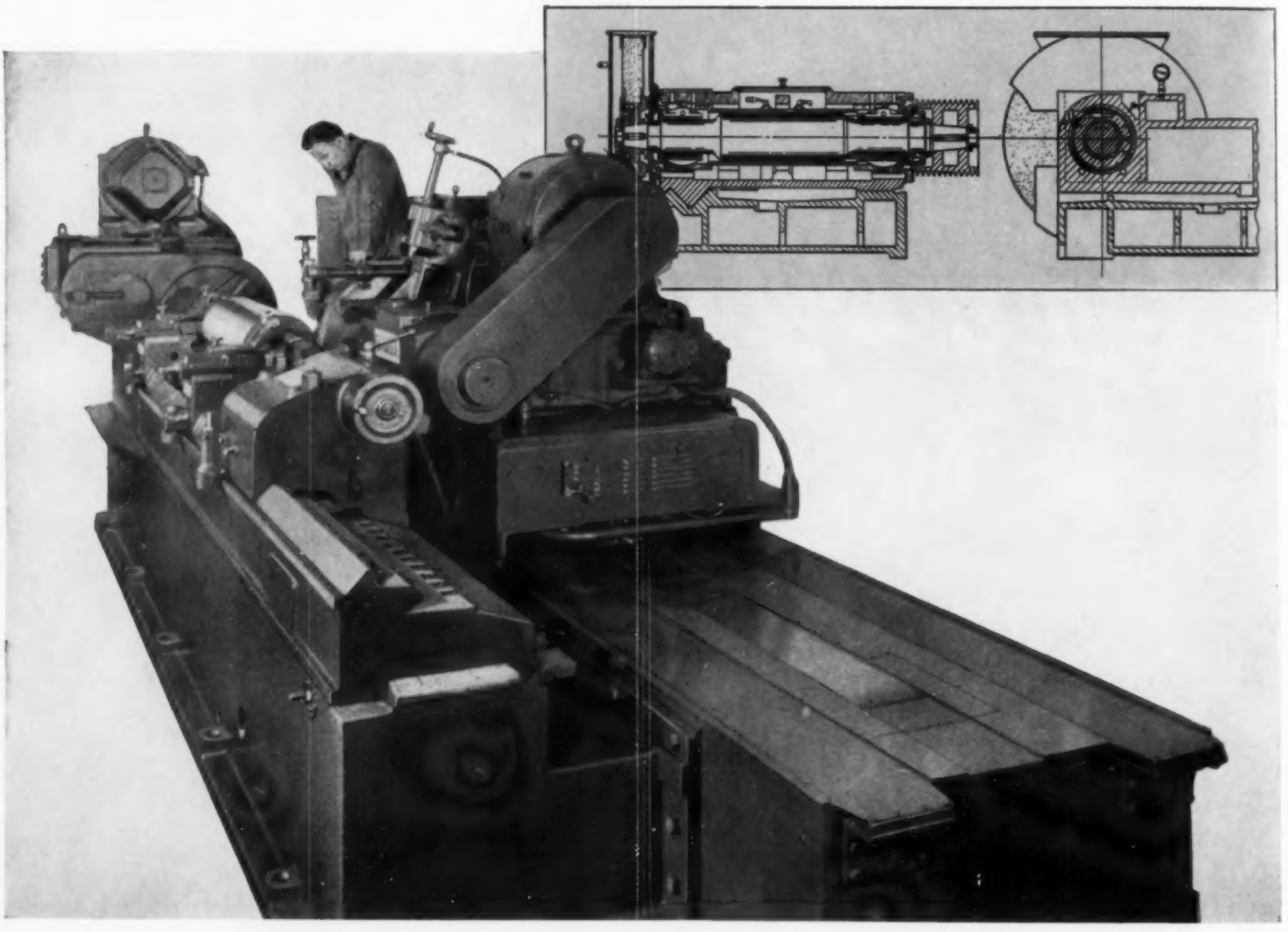
Spindle end thrust is taken by hardened steel thrust collars at the pulley end of the spindle. Grinding wheels and drive pulleys are end-mounted, permitting change of wheels and V-belts without disturbing either spindles or bearings.

Write for full details of this and other features of the improved Farrel HD roll grinder.

o

FARREL-BIRMINGHAM CO., INC.
Consolidated Machine Tool Division
ROCHESTER 10, N. Y.

Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y. *Sales Offices:* Ansonia, Buffalo, Rochester, Akron, Chicago, Fayetteville, (N. C.), Los Angeles, Houston. *European Office:* Piazza della Republica 32 Milano, Italy.



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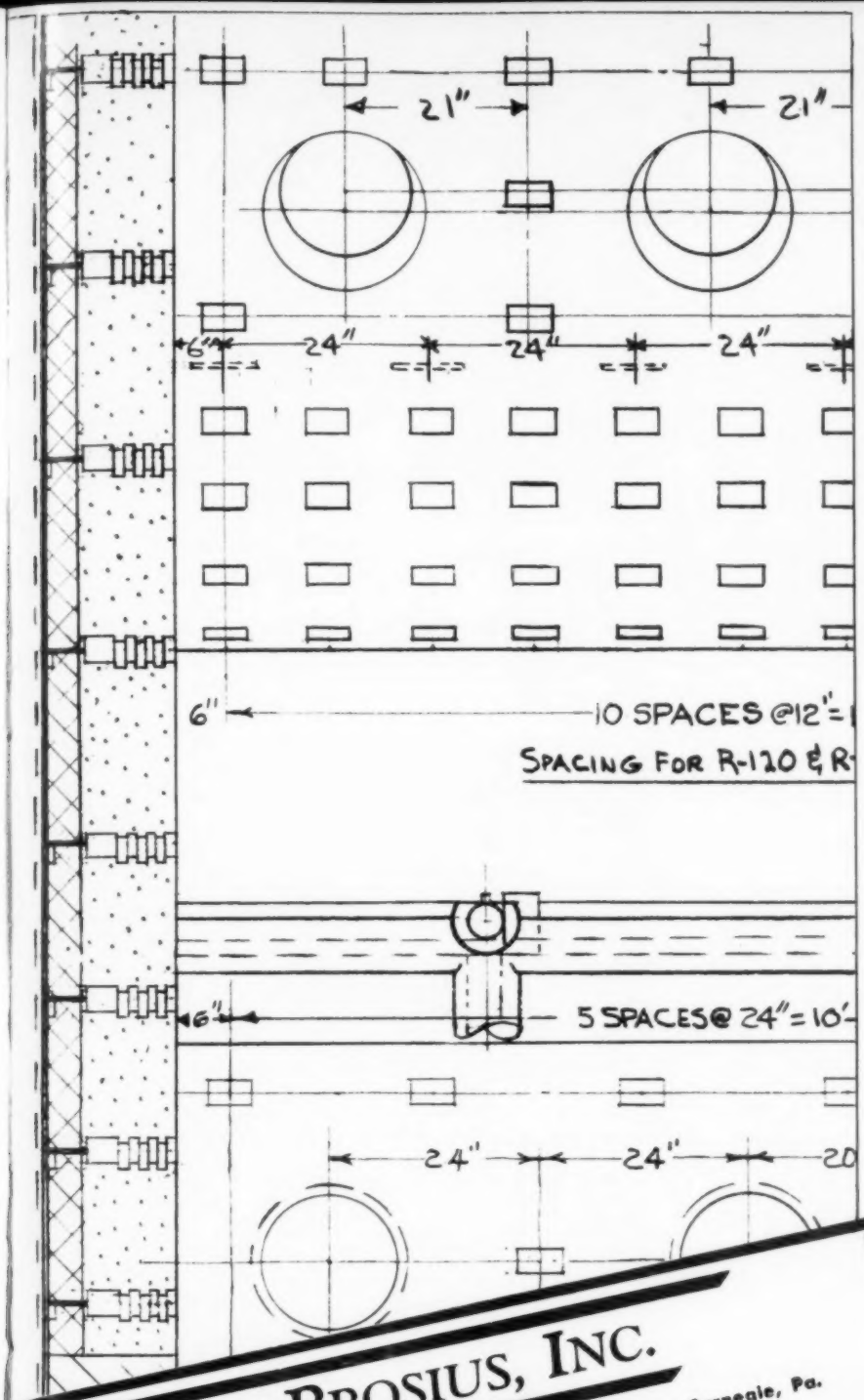
Rolls • Rolling Mills • Slab, Rod and Strip Handling Equipment • Roller Tables • Rod Coilers • Slitters • Gears • Gear Drives of Any Capacity • Mill Pinions • Pinion Stands • Universal Mill Spindles • Flexible Couplings • Roll Grinding Machines • Roll Calipers • Hydraulic Presses for Extruding, Forming, Drawing, Forging, Trimming, Hobbing, Straightening and Bending.

Farrel-Birmingham®

FB-1076



Proven Performance Paves the way to "New Furnace" Orders for RAMTITE®

Ramtite's cost reducing performance in an eastern steel mill led to this purchase order from Salem-Brosius, Inc. for Ramtite to line the burner walls, side walls and heating zone nose in each of three new slab heating furnaces.

Ramtite's monolithic construction eliminates joints...reducing air infiltration. Provides an air-tight, flame-tight, gas-tight structure which lowers steel production costs and assures long trouble-free performance.

The Ramtite Co. offers you a complete sales engineering service — experienced men who are always available to study your refractory problems and consult with your engineering, mason and ceramic departments about your specific needs.

For further information, contact your local Ramtite representative or mail the attached coupon.

SALEM-BROSIUS, INC.

Box 2222, Pittsburgh 30, Pa. • WAlnut 2-2200 • Office and Plant Carnegie, Pa.
• Salem Industrial Furnaces • Brosius Mechanical Equipment
Hagan Heating and Heat Treating Furnaces • Phillips Materials Handling Equipment

PURCHASE ORDER

3138-40-4 Supplem

PURCHASE ORDER NO. AND SELLER'S
NO. MUST APPEAR ON ALL INVOICE
AND BILLS OF LADING.

DATE January 18, 1956

ACCT. NO.

REQ. NO. WHR E581

DATE TO BE SHIPPED After April 1, 1956

F. O. B.

Ramtite Company
West Eighteenth Street
Illinois

The Ramtite Co.
DIV. OF THE S. OBERMAYER CO.

THE RAMTITE CO., Div. of The S. Obermayer Co.
1813 South Rockwell St., Chicago 8, Ill.

Please send items checked

- ☐ Bulletin on Ramtite Plastic Refractory in Steel Plant Furnaces.
- ☐ Bulletin on Castable and Gunning Refractories.

Company Name _____

Attn. Mr. _____ Title _____

Address _____

City _____ Zone _____ State _____

© 1956

This is another in a series of advertisements depicting ways Ramtite Refractories serve the steel industry.

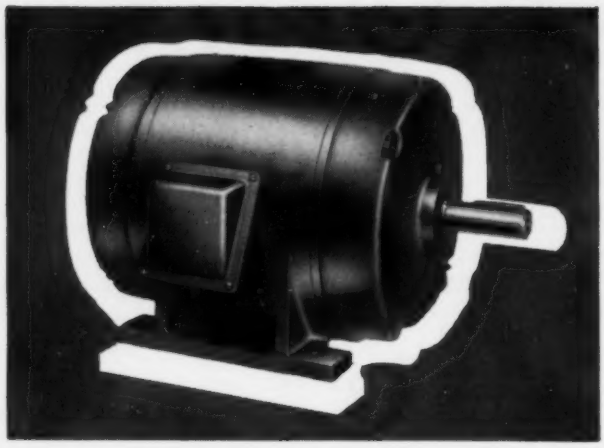
Wagner®
ELECTRIC MOTORS
... the choice of leaders in industry

You get better performance with these Wagner DP Motors

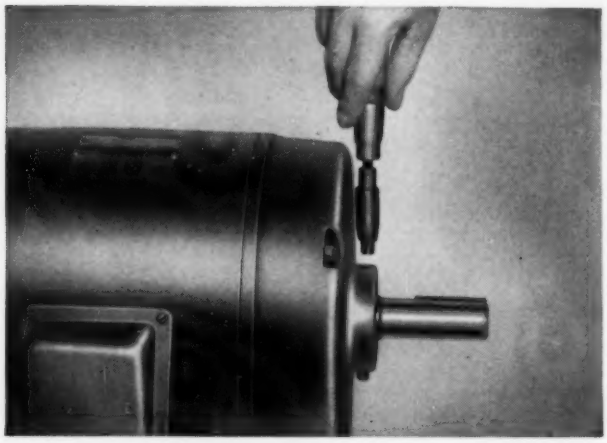
Wagner DP motors are *doubly protected* by (1) rugged, corrosion-resistant cast iron frames, smoothly rounded so that no moisture can collect on them. Motor feet are cast as an integral part of the frame for maximum strength and rigidity. (2) Enclosures on the DP motor are completely drip-proof—virtually splashproof. Air intakes are located at the bottom of the endplates and air outlets are located at the base of the frame—one on each side.

Although engineered to meet the re-rated NEMA specifications which call for more power in smaller frames, the same high quality and long life performance that have made Wagner Motors "the choice of leaders in industry" for many years has of course been retained.

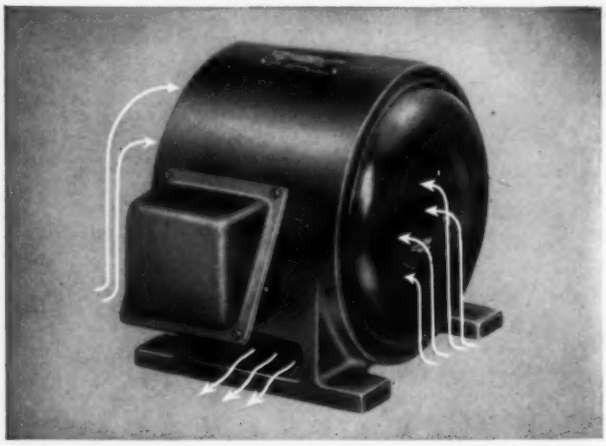
Full information and principal dimensions are given in Bulletin MU-202. Write for your copy today.



MORE POWER IN SMALLER FRAMES The Wagner DP Motor packs more power in a smaller frame and this smaller size means ease of handling and stocking ... less space required for installation.



CAN BE RE-GREASED FOR LONGER LIFE This motor will operate for years without regreasing ... bearings are completely enclosed ... however, provisions have been made for adding lubricant and for the removal of old grease in cases where re-greasing is necessary.



COOL RUNNING Specially designed baffles direct cooling air from the blowers through the motor and provide protection for the stator windings. Blowers are an integral part of rotor ... and move large volumes of air without noise or vibration.

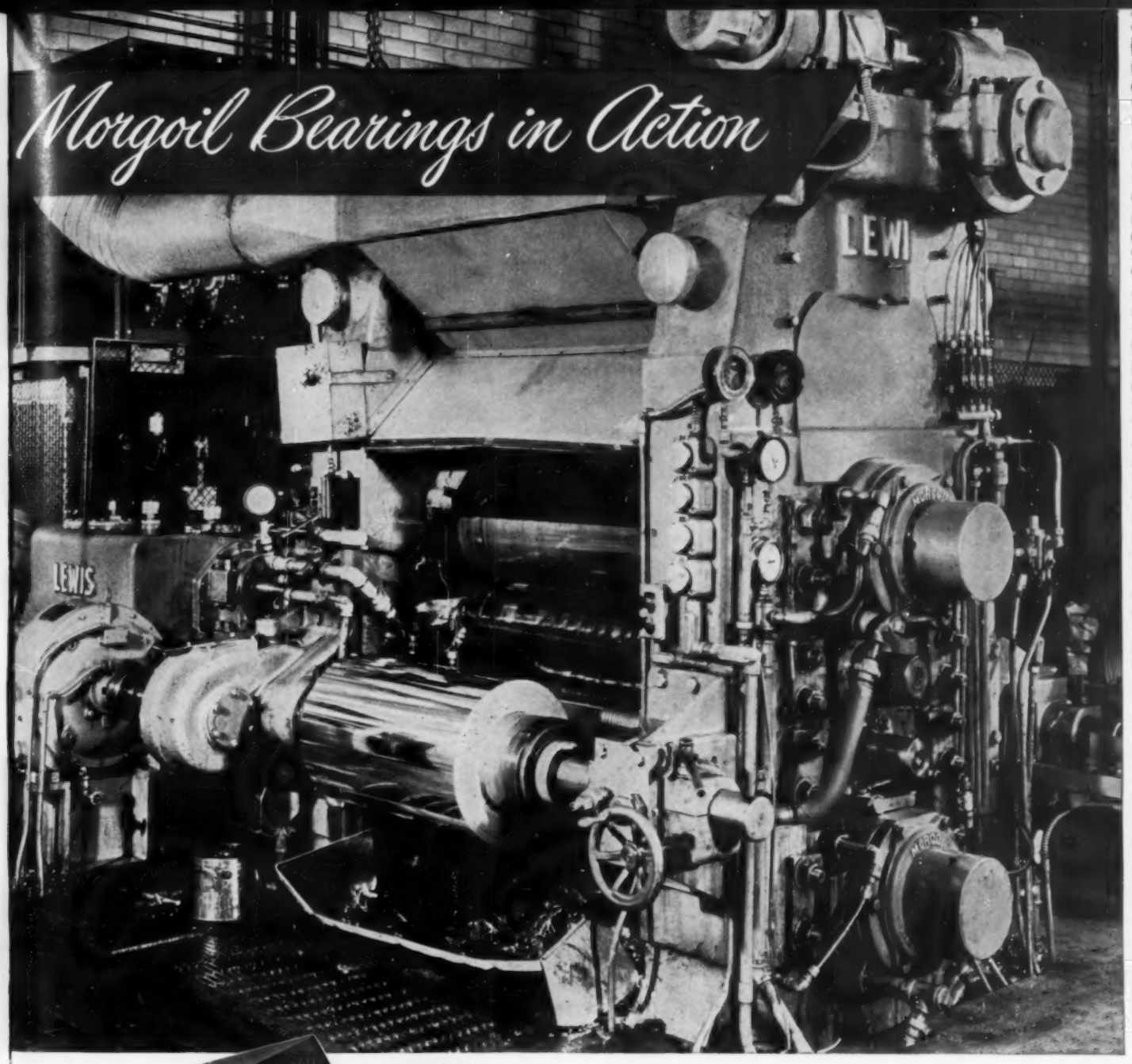
Wagner Electric Corporation
6483 **Plymouth Ave., St. Louis 14, Mo., U. S. A.**

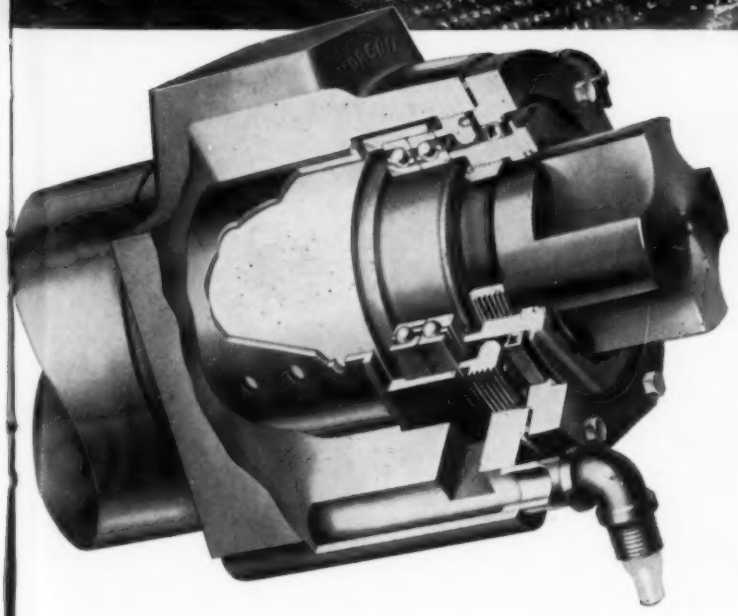
BRANCHES AND DISTRIBUTORS IN ALL PRINCIPAL CITIES

M56-4

ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES • AUTOMOTIVE BRAKE SYSTEMS–AIR AND HYDRAULIC

Morgoil Bearings in Action





The 18″-72″ MORGOILS on the 9″ and 21″ x 44″ Aluminum Foil Mill at Cochran Foil Co. pictured above make it easier to produce a quality product at high speed. Foil as thin as .00025 of an inch is rolled at speeds approaching 4000 feet per minute on MORGOIL-equipped mills. MORGOIL BEARINGS give you freedom from wear and fatigue and permit operation at high speeds with remarkable long bearing life.

MORGAN CONSTRUCTION CO.

WORCESTER, MASSACHUSETTS

ROLLING MILLS MORGOIL BEARINGS GAS PRODUCERS
WIRE MILLS EJECTORS REGENERATIVE FURNACE CONTROL

MB-31

MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER

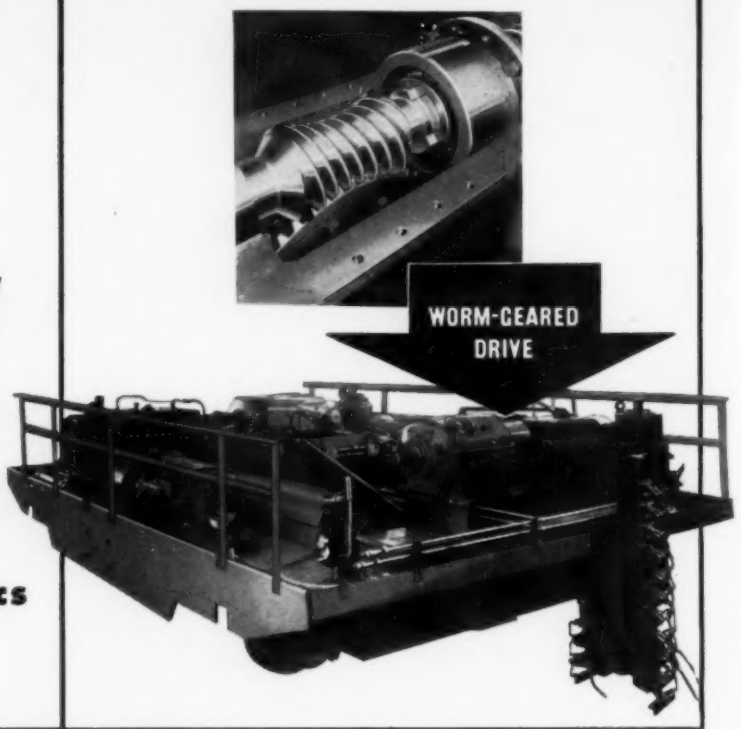
MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER

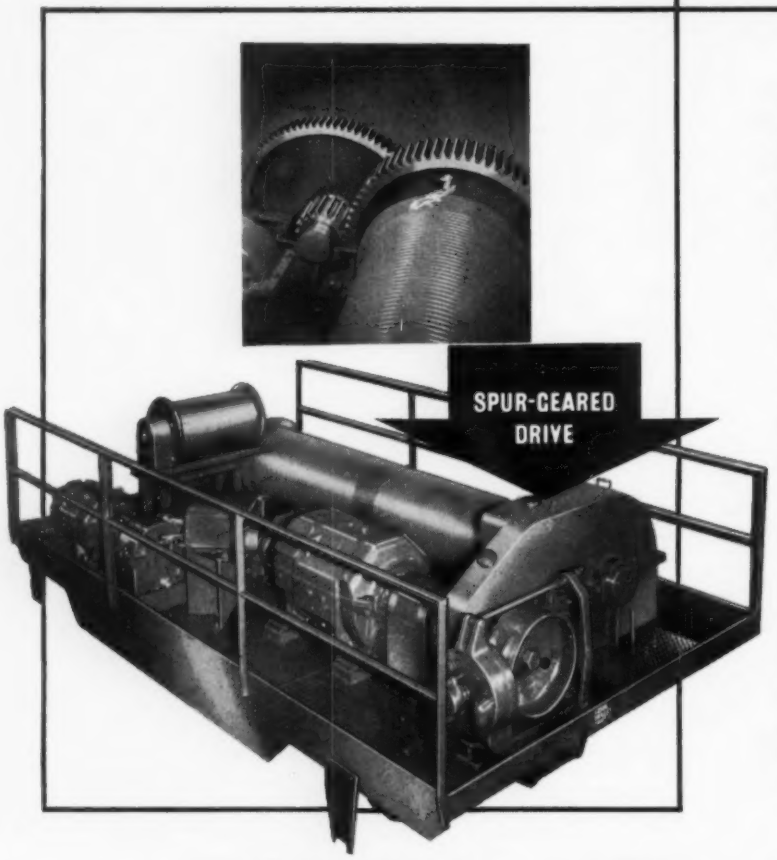
CHOOSE THE TROLLEY

YOU LIKE BEST

SHAW-BOX

Builds both to A.I.S.E. Specs





You want trolleys of the type your experience has proved are best for your particular requirements. The two types of trolleys and their gearing shown here illustrate how A.I.S.E. specifications are interpreted by Shaw-Box in satisfying the needs of two different mill applications.

Whether you prefer worm or spur gearing on your trolleys, turn to Shaw-Box and be sure of the finest in precision manufacture. Our long experience in designing, engineering and building load handling equipment exclusively assure you of continuously dependable performance, regardless of service conditions.

Over the years, we have produced many 5 to 200-ton cranes of various types to A.I.S.E. specifications and to the specifications of individual mills. Their work records prove the economic value of mechanical and operational features conceived and introduced by Shaw-Box. So if your plans include a crane to handle plate or slabs, a soaking pit carriage or a giant ladle crane, we invite your inquiry.

"Shaw-Box"® CRANES

MANNING MAXWELL & MOORE INC. M&M TRADE MARK

MANNING, MAXWELL & MOORE, INC.

SHAW-BOX CRANE & HOIST DIVISION, MUSKEGON, MICHIGAN

Builders of "SHAW-BOX" and 'LOAD LIFTER' Cranes, 'BUDGIT' and 'LOAD LIFTER' Hoists and other lifting specialties. Makers of 'ASHCROFT' Gauges, 'HANCOCK' Valves, 'CONSOLIDATED' Safety and Relief Valves, 'AMERICAN' and 'AMERICAN-MICROSEN' Industrial Instruments, and Aircraft Products.

56K-2 A-665

Bearings, Inc.

the maintenance man's friend . . . through service!

Dirt . . . the most feared enemy of any good anti-friction bearing was damaging many bearings in the maintenance stock at the Taylor and Boggis Foundry Division of The Consolidated Iron-Steel Mfg. Co. of Cleveland, Ohio. John Cunin, Bearings, Inc. salesman, was called and within a short time, under the direction of the Taylor and Boggis Maintenance Superintendent reorganized their maintenance stocks of bearings and developed a more practical record keeping system.

First—all bearings in stock long enough to be affected by foundry dust were taken to Bearings, Inc. There, they were thoroughly cleaned, rewrapped and repackaged to be as dustproof as possible.

Second—all bearings in use in the foundry were identified by the Bearings, Inc. salesman according to the bearing manufacturers' numbers. By converting the equipment manufacturers' parts numbers to standard bearing numbers, many bearings purchased from various sources under a variety of parts numbers were found to be identical.

Weeding out these duplicates greatly reduced Taylor and Boggis purchases for inventory. Bearings, Inc. now knows what bearings the foundry uses and makes certain stocks for any emergency are carried at our branch. Taylor and Boggis now installs only factory-fresh bearings from inventory or orders from Bearings, Inc. and receives the bearings they need immediately.

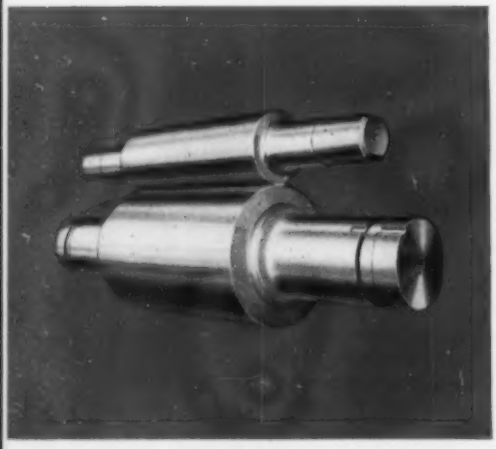
Need this kind of service—service with a capital "S"? Just call our nearest branch—no obligation, of course.

Rendering bearing service in the territories adjacent to our branches, listed below.

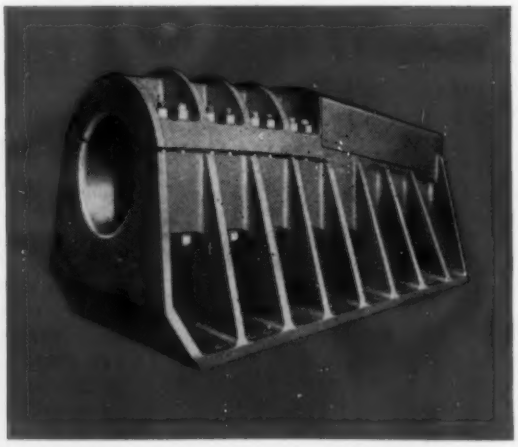
BEARINGS, INC.

OHIO: Akron • Canton • Cincinnati • Cleveland • Columbus • Dayton • Elyria • Hamilton • Lima • Mansfield • Toledo • Youngstown • Zanesville
INDIANA: Ft Wayne • Indianapolis • Muncie • Terre Haute
PENNSYLVANIA: Erie • Johnstown • Philadelphia • Pittsburgh • York
WEST VIRGINIA: Charleston • Huntington • Wheeling
NEW JERSEY: Camden • **MARYLAND:** Baltimore
Subsidiaries: Balanrol Corp. • Buffalo, N.Y. • Kentucky Ball and Roller Bearing Co. • Louisville, Ky.

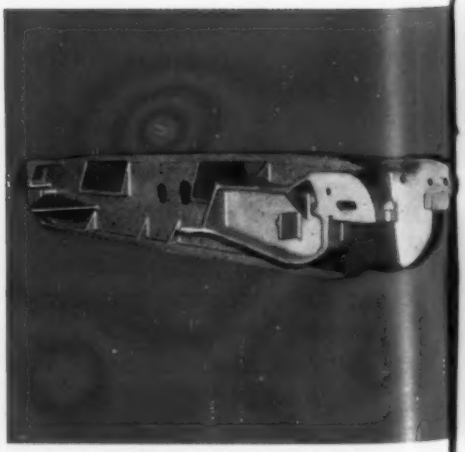
CONTINENTAL 26″ x 49″ x 66″, 4-high reversing hot strip mill in the Newport Steel Corporation Plant, Newport, Kentucky.



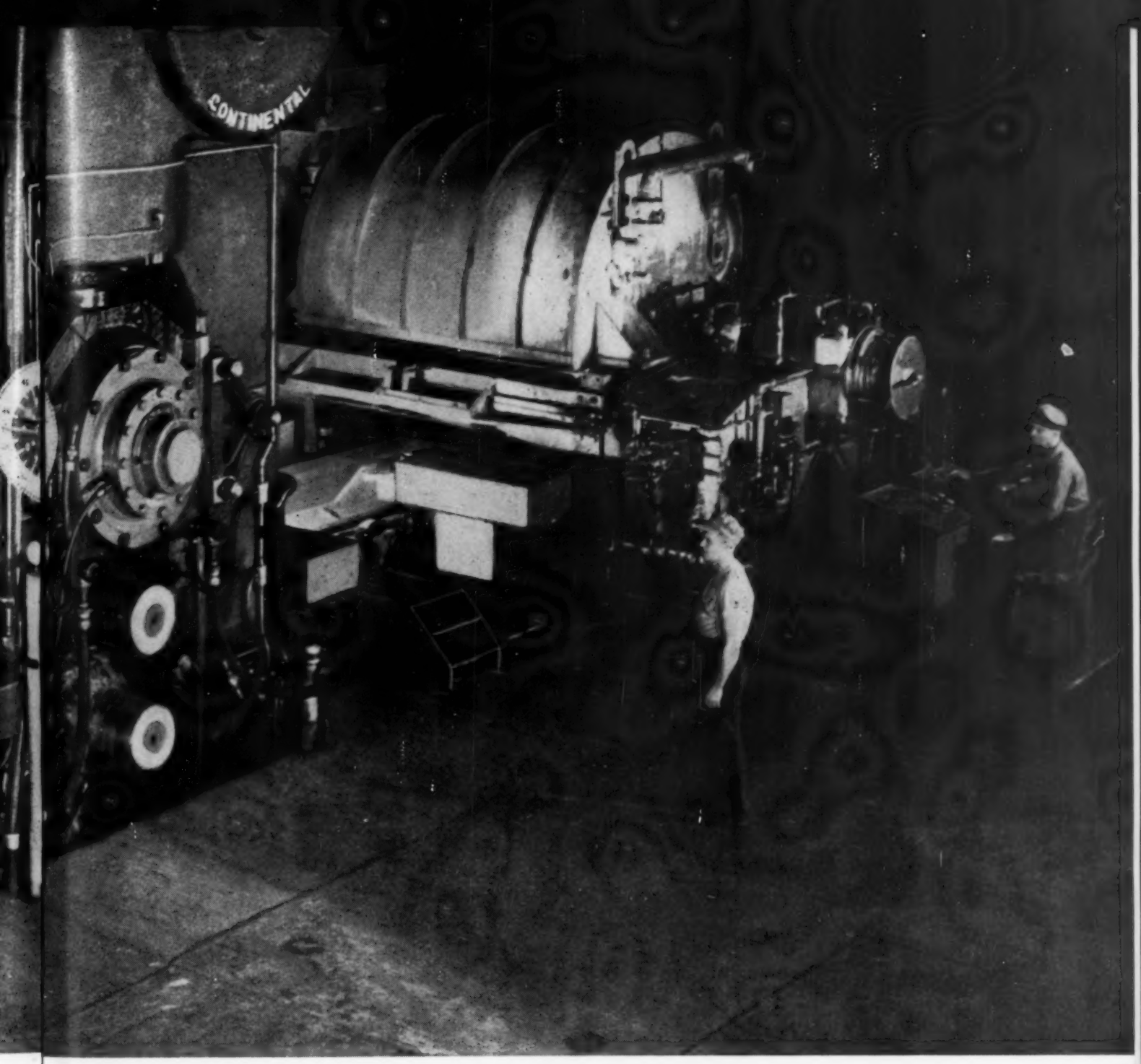
ROLLS—iron, alloy iron and steel rolls for all types of rolling mills.



CASTINGS—carbon and alloy steel castings from 20 to 250,000 pounds.



WELDMENTS—fabricated steel plate, or cast-weld design.



BLAW-KNOX *makes what it takes*

to roll precision-gage hot strip directly from ingots

Precision-gage hot strip is rolled directly from ingots by this modern CONTINENTAL 66-inch 4-high reversing hot strip mill in the Newport Steel Plant at Newport, Kentucky.

A full range of gages and analyses, including carbon and special grades of steel, are rolled by this 26″ x 49″ x 66″ mill. The mill was designed to incorporate an existing 4000 hp. d.c. reversing motor through a pinion stand.

Blaw-Knox designs and builds *complete* rolling mill installations—assumes undivided responsibility from preliminary engineering to satisfactory operation. At any time we'll be glad to discuss your plans with you.

BLAW-KNOX COMPANY
Foundry and Mill Machinery Division
Blaw-Knox Building • 300 Sixth Avenue
Pittsburgh 22, Pennsylvania

Complete Rolling Mill Installations . . . including all auxiliary equipment . . . for ferrous and non-ferrous metals

Hot strip mills • cold strip mills • slabbing mills • temper mills • universal mills • plate mills • blooming mills • structural mills • rail mills • billet mills • rod mills • merchant mills • roll lathes • chippers • special machinery • and complete auxiliary equipment.

50th Anniversary
BLAW-KNOX
1906-1956

CONTINENTAL

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

5031 EAST 289th ST.
WICKLIFFE, OHIO

Crops and Shorts

OCTOBER lived up to its reputation as a month of records, with many plants and companies hitting new production peaks, all combining to set a new national record at 11,048,513 net tons of ingots — the first time above 11,000,000.

▲

INDUSTRY is widening the scope of its hunt for engineers. Carnegie Institute of Technology reports a large increase in the number of interviewers visiting the campus. Jones & Laughlin Steel Corp. and several other companies have put out booklets designed to interest students in the respective companies. Koppers Co. has set up a manager of manpower planning and director of college relations and recruitment. Young engineers are really in clover. New graduates start at salaries of $4500-$5700, and Ph.D.'s at $7200-$9000. Do you fellows who started 20 to 30 years ago remember your starting salary?

▲

A side light on the engineer shortage may be seen in the decision of the Aircraft Industries Association to junk its no-raiding resolution.

Enticements range from fancy planes to bring in prospects to free week-ends on Bourbon Street in New Orleans.

▲

THE Value Line Investment Survey predicts steel ingot production at 110,000,000 tons for 1957, giving unbalanced demand as the cause of the production demand. The forecast sees continued pressure on heavy steel supplies, with lessened demand for steel from consumer goods industries.

▲

ON the other hand, Max D. Howell, executive vice president of the American Iron and Steel Institute, sees highway construction taking 49,000,000 tons of finished steel in 13 years, plus large additional tonnages for road building machinery. Other important prospects include pipeline construction, shipbuilding, the St. Lawrence seaway, power plant construction, and a more active freight car program.

▲

ALSO, the Value Line Investment Survey sees the machinery industry shipments at a possible peak in 1957, but principally due to the time-lag between order and shipment. The survey believes, however, that the machinery industry will continue to grow at a rate faster than the economy as a whole.

SEVERAL items in the papers recently reported results of voting by various locals of the United Steel Workers on the increased union dues. How they voted is not important, but it is disturbing to see locals of 4000 to 10,000 members deciding things by votes of 87 to 65 or thereabouts. It is this sort of minority rule that leads to abuses.

▲

OUR last-month inauguration of STASCIDOA (that stands for Society to Abolish Senseless Changes in Design of Automobiles) seems to have struck a responsive chord. One reader complains about frequency of repairs on today's cars. Another thinks that we'd have much better cars if half the effort now devoted to "gingerbread" on automobiles were to be expended on reliability and economy.

We didn't think we were alone in our complaint about new car design.

▲

RUSSELL L. PETERS, vice president of Inland Steel Co., feels that corporations must be allowed to depreciate assets at current replacement cost. Construction costs have increased at an annual average rate of seven per cent compounded since 1940. Hence, replacement of an asset after a useful life of 25 years will require 5.43 times as much as the original price. Mr. Peters sees the present emphasis on full employment and free bargaining as seeds of continuous, creeping inflation, and emphasizes that the use of retained earnings to supplement inadequate depreciation for replacing worn-out assets is itself inflationary. Earnings are available only after taxes, so that for every $100 needed, prices must be high enough to provide $208.33 in earnings before taxes. This means high prices.

▲

FROM Typographic:

I don't want a lot of money;
I'd be satisfied, I vow,
If I could just afford to live
The way I'm living now.

▲

THE Technology Department of Carnegie Library of Pittsburgh has been made the first deposit center for the reports of the Office of Technical Services, Department of Commerce. This means that technical data derived from research done for and by the government at a cost of more than $2,000,000,000 per year will be more convenient for industry. This research touches many fields of industry, including metals, chemicals, plastics, electronics, foods, fuels, instruments, leather, rubber, geology, mineralogy, metallurgy and ceramics.

▲

STATISTICS from an American Iron and Steel Institute study show that 204 of the open hearth furnaces in the country are larger than 225 tons, while there are still five furnaces under 100 tons.

▲

IT doesn't seem possible that a year has passed since we did this, but it's time again, so: "MERRY CHRISTMAS and HAPPY NEW YEAR."

Follow The Leaders...

Use Automatic Electric Trucks

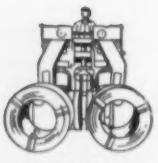
Carrying approximately 6100 pounds per load, a fleet of Automatic Electric Trucks like the two above work around the clock, 365 days a year, in the hammer shop of a leading automobile manufacturer. Your own requirements may not be equally severe but all Automatic Electric Trucks are engineered to give comparable service when needed.

They work, too, for pennies an hour—cost less per year to own and less to operate...last years longer with only negligible down time.

Experienced operators invariably favor Automatic Electric Trucks, too, for the smooth, fume-free ride with no gear shifting, safer low center of gravity, and smoother handling in tight quarters. In short, Automatics excel in every wanted lift truck quality.

There's a model, too, that's exactly suited for your requirements. You'll find it fully described in Automatic's new 16-page catalog of America's most complete line of electric-driven trucks. *Write for your copy today.*

Address: Automatic, 47 West 87th Street, Dept. X6, Chicago 20, Illinois



SKYLIFT GIANT With fork or ram, capacities to 100,000 lbs.

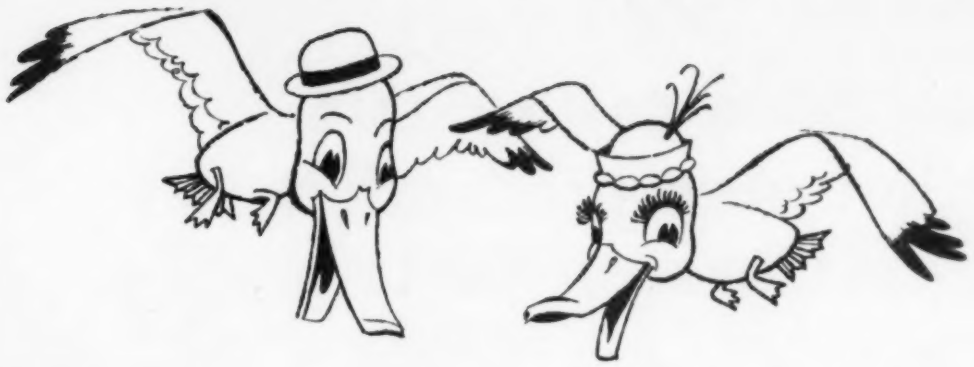
DOCKER—for congested areas: 1,000 to 3,000 lbs.

LOW PROFILE SKYLIFT—Safer in low clearance areas: 1,000 to 4,000 lbs.

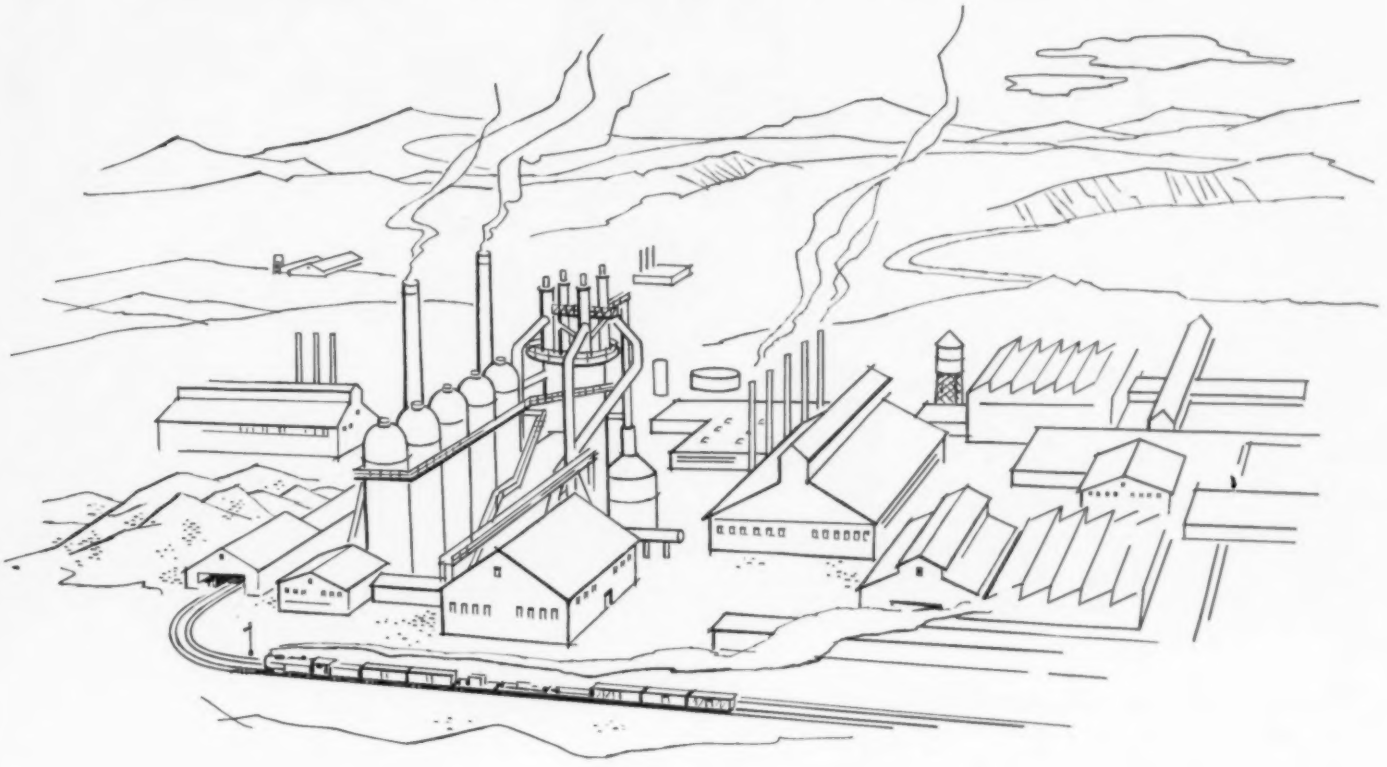
TRANSVEYOR—for narrowest aisles. 2,000 to 4,000 lbs.

50th Automatic Anniversary

WORLD'S LARGEST EXCLUSIVE BUILDER OF ELECTRIC-DRIVEN INDUSTRIAL TRUCKS

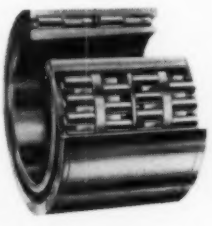


Production is smooth as water rolling off your back!



No wonder: **SKF**® has developed a roll neck mounting that meets the demands for higher speeds, closer gauge tolerances, better quality and heavier rolling loads. This multi-row has the features desired by every mill man – most usable capacity in a given space... easy to assemble and disassemble... uses oil or grease, even at high finishing stand speeds.

When you install a new mill, make sure it is equipped with **SKF** multi-row cylindricals. Or have an **SKF** engineer explain how your present mill can be changed over at minimum cost to eliminate roll neck troubles such as breakage, scuffing, excessive bearing failures or high maintenance time and cost. 7737



SKF

EVERY TYPE—EVERY USE

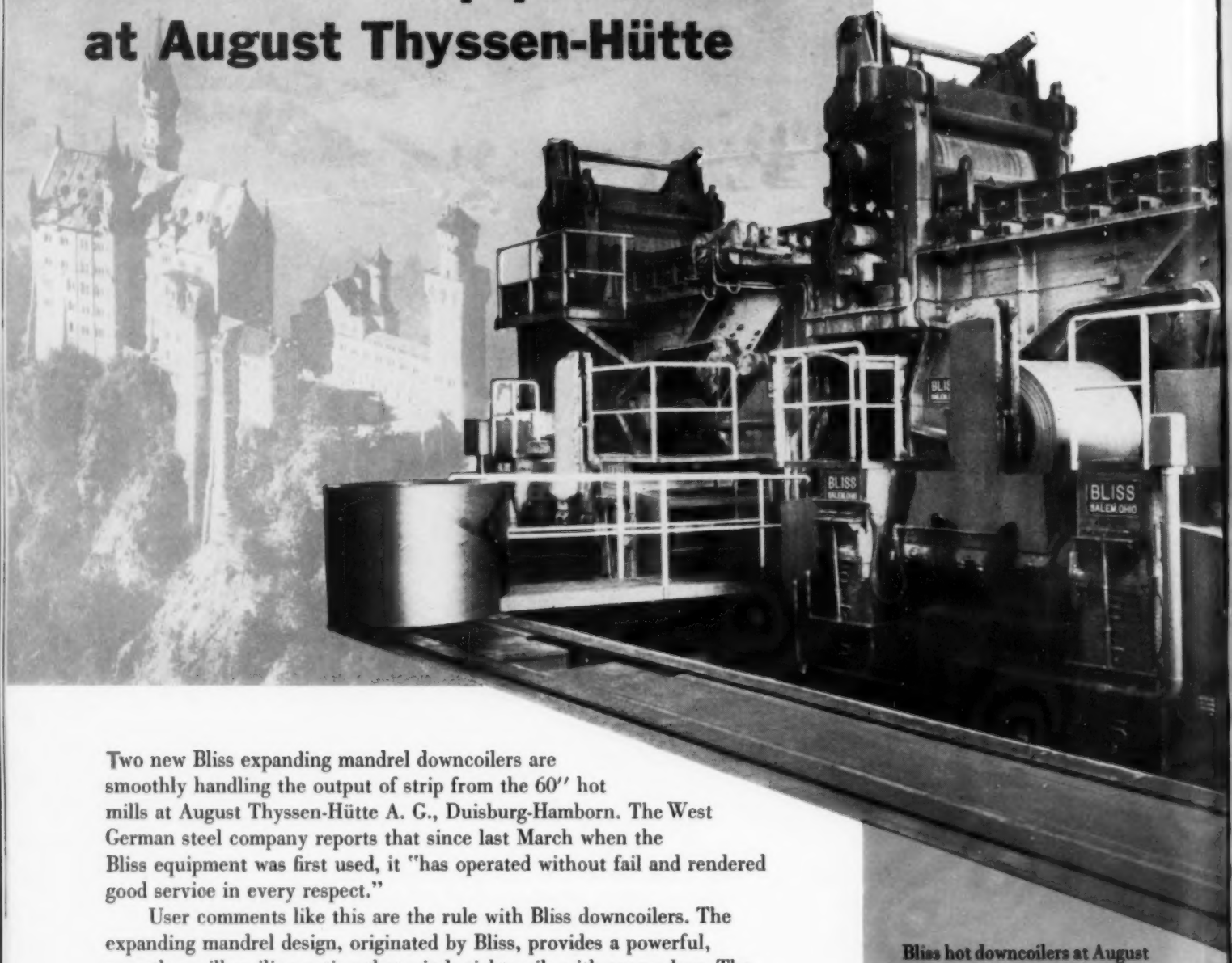
- *Ball Bearings*
- *Cylindrical Roller Bearings*
- *Spherical Roller Bearings*
- *Tapered Roller Bearings (Tyson®)*

® Reg. U.S. Pat. Off. Tyson Bearing Corporation

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

In Germany:

two new Bliss downcoilers insure hot strip production at August Thyssen-Hütte



Two new Bliss expanding mandrel downcoilers are smoothly handling the output of strip from the 60″ hot mills at August Thyssen-Hütte A. G., Duisburg-Hamborn. The West German steel company reports that since last March when the Bliss equipment was first used, it "has operated without fail and rendered good service in every respect."

User comments like this are the rule with Bliss downcoilers. The expanding mandrel design, originated by Bliss, provides a powerful, smooth-as-silk coiling action that winds tight coils with even edges. The blocker rolls touch the strip only when the initial wraps are made and the ends are being taken up. Thus, there is no scratching or surface damage during coiling.

You'll find Bliss equipment . . . and satisfied users . . . in rolling mills all over the world. To acquaint yourself with our products, why not write today for a copy of our 60-page Rolling Mill Brochure, Catalog 40-A? It's yours for the asking.

E. W. BLISS COMPANY
General Office: Canton, Ohio
ROLLING MILL DIVISION: SALEM, OHIO

BLISS
SINCE 1857

is more than a name . . .
it's a guarantee

Bliss hot downcoilers at August Thyssen-Hütte coil strip in widths from 24″ to 60″. Mandrel diameter is 28″, and maximum coil O.D. is 56″. The two upenders were also designed and built by Bliss.

PLANTS: Canton, Cleveland, Salem and Toledo, Ohio; Detroit and Hastings, Mich.; Pittsburgh and Midland, Pa.; San Jose, Calif. *In Europe:* E. W. Bliss (England) Ltd., Derby; E. W. Bliss Co. (Paris), France.

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Empire Building
Pittsburgh, Pa.

Iron AND Steel ENGINEER

DECEMBER, 1956 VOLUME XXXIII NUMBER XII

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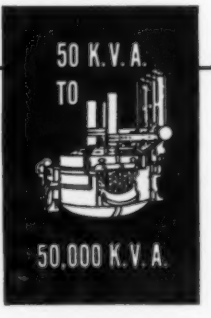


Rolling of Thin Strip | Part II

By M. D. STONE
Manager, Research and Development, United Engineering and Foundry Co., Pittsburgh, Pa.

. . . . data in following paper and methods outlined enable the designer to predict mill pressures and powers which are required for rolling of metals . . . . procedure starts with certain fundamental data and recognizes the various limiting conditions which are encountered in rolling . . . . factors apply equally well to hot and cold rolling of thick strip . . . . this article supplements a previous article published in the February, 1953 Iron and Steel Engineer . . .

▲ THE subject of the rolling of thin strip was first discussed in some detail in the original paper[23]*, of which this is a continuation. See pp 115-128, 1953 Proceedings AISE. At that time, the theory of thin strip rolling was presented, and it was shown that it was possible to quite accurately predict rolling performance, i.e. rolling pressure, powers, gage variations, etc. The considerable importance of work roll diameters, roll bite friction, etc., were shown to be closely tied to the parameter, $\frac{\mu L}{t}$, where

μ = roll bite friction
L = flattened roll contact length
t = strip thickness being rolled (average)

In fact, the actual specific rolling pressure in the bite is related to the basic compression resistance of the particular metal being rolled by a Pressure Multiplication Factor (PMF) evaluated as

$$PMF = \frac{e^{\frac{\mu L}{t}} - 1}{\frac{\mu L}{t}}$$

From this, it can be appreciated that as the thickness of the strip being rolled is decreased, the parameter $\frac{\mu L}{t}$ increases, and the PMF value increases much more rapidly (exponentially), showing how rolling difficulties are multiplied. The recourse is, of course, to reduce μ and L, to offset the smaller value of t. The value of L can be decreased by using smaller work roll diameters, and μ can be decreased by the use of better lubricants, or rolling at higher speeds.

The matter of small work rolls has received a great deal of attention in recent years, leading some people to consider the adoption of ultra-small work rolls as a necessary expedient. The original paper showed how the small work roll, back-up driven 4-high mill has worked out as the most suitable, from an overall point of view for the high speed rolling of thin strip. Since that time many more such mills have gone into operation, now covering such applications as aluminum foil rolling at 3000 fpm and above, rolling of copper and its alloys, reduction of medium and high carbon steels in reversing mills, temper passing of tin plate at speeds of

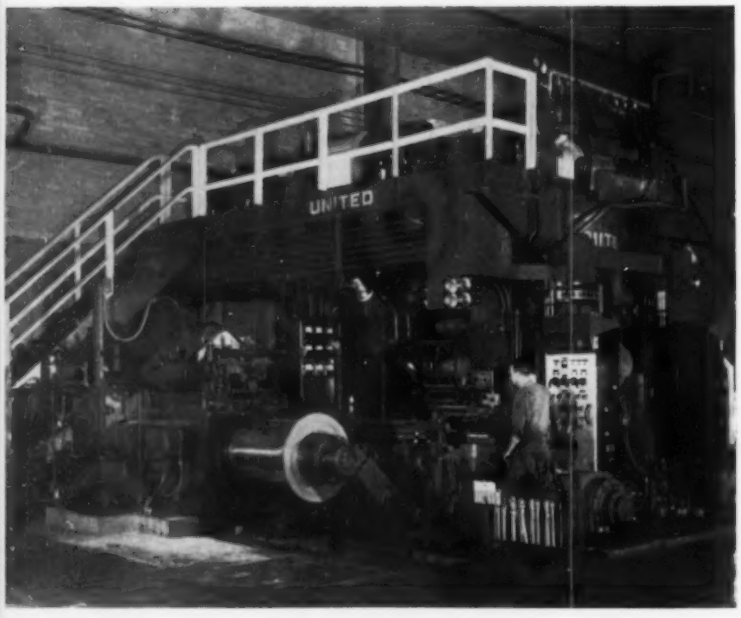
Presented before AISE Annual Convention, Chicago, Ill., September 26, 1955.

*Numbers refer to Bibliography at end of paper.

5000 fpm and more, production of silicon steel strip and all grades of stainless strip, and more latterly the rolling of titanium and titanium alloy strip to light gages. In addition, some of the constructional advantages of this type of mill — such as the lack of necessity of matching work rolls or back-up rolls, where they are separately driven (preferably); ease of changing work rolls; possibility of varying work roll size, according to analysis and thickness of metal being rolled, without sacrificing production speed; etc., have led to its adoption for medium and heavy strip cold rolling, as well.

A detailed study of the role and influence of roll bite friction was also carried through in the first part (Part I) of this paper. And it is believed that for the first time, it was demonstrated that gage variation in cold rolling was explained as due to bite friction variation, or at least equivalent bite friction variation— specifically, for instance, the decrease in gage as rolling speeds increase, and the converse, namely, the increase in gage (usually beyond permissible tolerance) at the beginning and the end of each coil being rolled, where the speed is necessarily reduced. Other effects, such as variable deformation resistance as a function of strain rate (speed), varying strip temperature in the bite, changing oil film thickness in the back-up bearings (when film bearings are employed) or corresponding roller contact variations in back-up roller bearings, were relegated to a category of secondary magnitude. BISRA, in a subsequent report ([24]), went into this matter more exhaustively, and came to the same conclusion. It is interesting to see how close the two papers agree, even quantitatively, by comparing Sims' Figure 6 with the author's Figure 5 — both showing a drop in the value of μ of about 40 per cent in going from 0 to 300 fpm — which is indeed a considerable variation. It seems well demonstrated then, that in spite of high specific rolling pressures of around 300,000 psi, hydrodynamic or pseudo-hydrodynamic effects still exist in the bite, in that higher speeds of up to 1000 fpm, show a decrease in μ to 0.03 to 0.04 from an initial value at low speeds, of around 0.10. It, of course, is to be appreciated that these values of μ were not obtained from direct measurement experiments, but were arrived at by working back from rolling tests, utilizing the rolling theory developed in Part I. In recently reading the printed discussion on Mr. Sims' paper, published in the August 1953 issue of the Journal of the Iron and Steel Institute, it was learned that Dr. H. W. Polakowski stated that neither Sims nor the present author had properly recognized his earlier publications on this point — referring to his article entitled "The Compression Test in Relation to Cold Rolling" — Journal of Iron & Steel Institute, November 1947, and a subsequent publication in Sheet Metal Industries, November 1951. In these articles, Mr. Polakowski referred to the earlier work of Ford([10]), who discussed a wide range of possible speed-dependent variables as the cause of gage variations and rejected the idea of bite friction as the main variable, based on his tests. Polakowski, however, took the point of view that bite friction was the main variable, but offered no calculations or experimental evidence to support the contention — referring to Ford's own tests as evidence enough, and also referred to the 1948 paper of Nekervis and Evans([15]), whose values of μ, by the way, were calculated from tests (limited as to speed) after consultation with the present author, using the latter's rolling theory. Trinks([13]), much earlier, cited considerable evidence for the variation of μ with speed. It is the present author's feeling, however, that to establish the point, an evaluation of μ in the bite based on actual tests, had to be carried through and an association established between it and gage — as was done in Part I, and also by Sims. Sims, following along this idea further, rather ingeniously reasoned that if a lubricant could be found whose μ was not a function of speed, then no gage variation would be involved. And indeed he carried out experiments with colloidal graphite, talc, and vermiculite — and demonstrated the point. Unfortunately, these solid lubricants have too many other disadvantages — such as poor roll cooling characteristics, difficulty of application, strip staining and poor surface finish, comparative high cost, etc., but their experimental use seems certainly to prove the point as to the relationship between gage variation and bite friction variation.

Figure 15 — This 5/10 and 43 x 44-In. 4-high mill in operation at Crucible Steel's Midland works is designed for rolling of thin, hard alloy strip such as stainless and silicon steels, titanium and its alloys.



More recently, a paper by Whitton and Ford([25]) describes an extended series of experiments carried out under rolling conditions, so conducted that rolling theory is not involved in their interpretation, in which values of μ are obtained in substantial agreement with those calculated by us from rolling tests — enhancing our conviction as to the value of our simplified theory. Unfortunately, the experiments were limited as to speed effects, a variation of 30 to 160 fpm showing only a 2 to 3 per cent drop in the value of μ.

A result of primary importance, showing the influence of work roll diameter, D, and bite friction, when rolling thin strip, was obtained in the recognition that there is such a thing as a limiting thickness (or thinness) in rolling. This relationship, as given by equation (12) is

$$t_{min} = 3.58 \frac{D\mu\ (s_o - s)}{E}$$

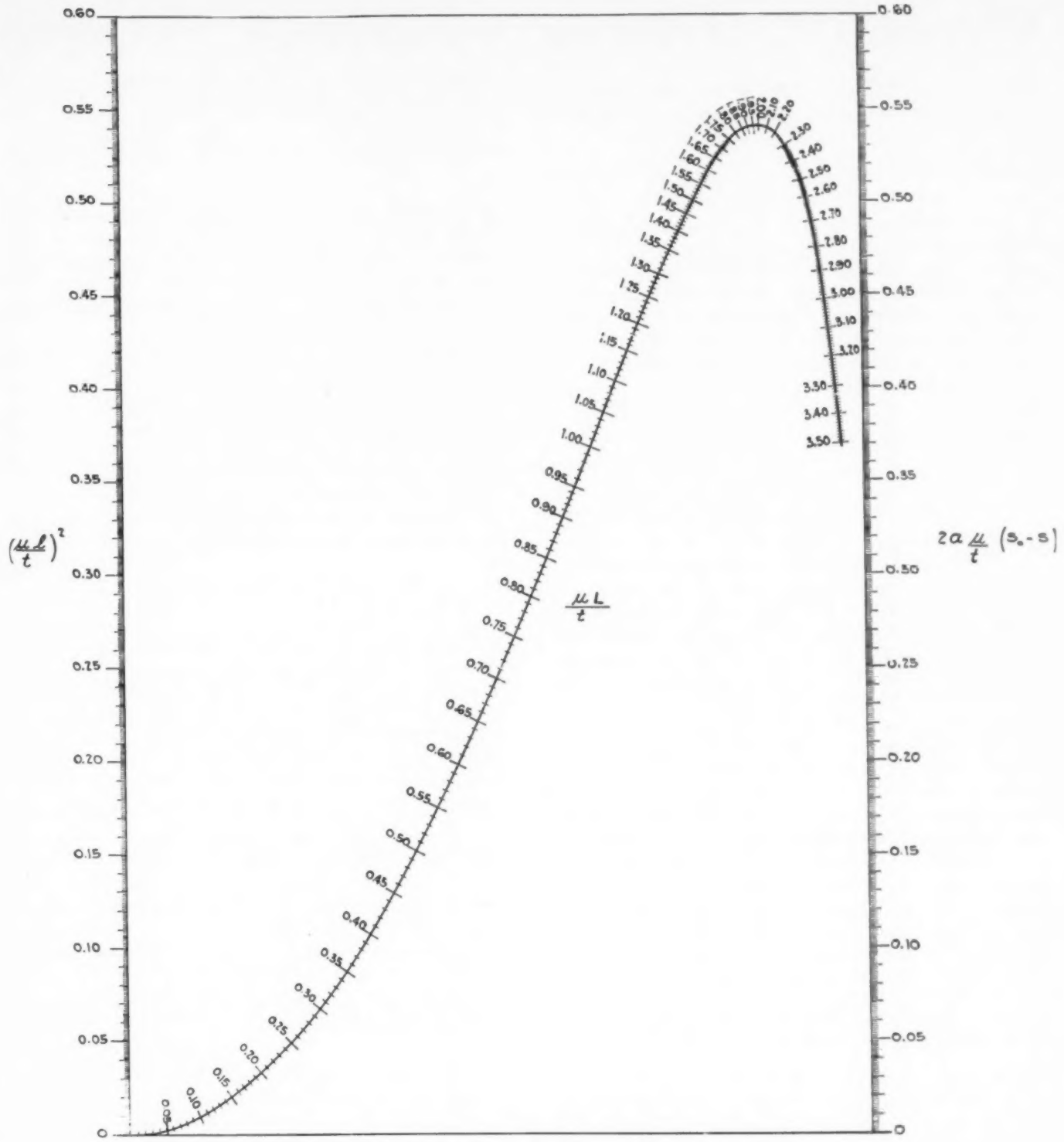


Figure 16 — Nomographic chart can be used for determining rolling pressures and powers.

— and necessarily introduces other important collateral factors, such as metal deformation resistance, strip tension, and work roll modulus of elasticity.

Returning now to the end of the original paper, it was stated that a nomographic chart had been worked out that reduced the time required for the step-by-step calculation procedure, detailed in Part I, from hours to minutes. We now wish to present this chart, and its development — as well as some power phenomena associated with high pressure, thin strip rolling.

Let us now start with equations (9) of Part I, and specifically (9b). By transposing, and squaring, we obtain

$$\left[\left(\frac{\mu L}{t}\right)-\left(\frac{\mu a}{t}\right)\bar{p}\right]^2=\left(\sqrt{\left(\frac{\mu l}{t}\right)^2+\left(\frac{\mu a}{t}\right)^2\bar{p}^2}\right)^2, \text{ or}$$

$$\left(\frac{\mu L}{t}\right)^2-\left(\frac{\mu l}{t}\right)^2=2\left(\frac{\mu L}{t}\right)\left(\frac{\mu a}{t}\right)\bar{p} \quad \ldots\ldots\ldots (16)$$

and by substituting for $\bar{p}$, its expression as given by equation (9a), we obtain finally

$$\left(\frac{\mu L}{t}\right)^2=\left(e^{\frac{\mu L}{t}}-1\right)2a\,\frac{\mu}{t}\left(s_o-s\right)+\left(\frac{\mu l}{t}\right)^2 \quad \ldots (17)$$

Remembering that $a = \frac{8(1-\nu^2)}{\pi E} R$ (See first paper) and is a constant for any given mill, and that $l = \sqrt{R(t_1 - t_2)}$, it is seen that equation (17) gives us a single explicit basis for obtaining $\left(\frac{\mu L}{t}\right)$, and hence L, the actual flattened contact length — from which all other important items of information stem, as was evident in the calculation procedure given in Figure 7, of Part I. Actually, equation (17) is a non-linear transcendental equation, and is impossible of analytic solution — and actual solution is conventionally by some step-by-step or trial-and-error method, similar to that resorted to in Part I. It is possible to plot, however, a family of curves of $2 \alpha \frac{\mu}{t}(s_o - s)$ vs $\left(\frac{\mu l}{t}\right)$ — for various assigned values $\left(\frac{\mu L}{t}\right)$, as has been carried out in appendix A. We see, however, a confusion of overlapping curves, particularly when all the curves are plotted that we should have for accurate calculation — see Figure 24, Appendix A. Certain generalities are interesting, however, as worked out in this appendix, particularly as to the clarity of presentation of the domains of rollability and non-rollability.

The preferred way to solve, practically, equations of this type is to resort to the science of nomography, which is a branch of mathematics concerned with the graphical solution of equations connecting three (or more) variables. The idea is to construct three separate scales, one for each variable — that may be intersected by a straight line in such a way that the three intersection points constitute a solution of the equation involved. Not all equations can be handled in this manner, but where they can, the nomographic chart solution offers the advantages of: easily read charts, involving a minimum of lines; interpolation along a scale rather than between curves resulting in greater accuracy; greatly decreased labor of construction; and ready evidence of interdependence of the variables.

By calling $x = \left(\frac{\mu L}{t}\right)$, $y = 2 \alpha \frac{\mu}{t}(s_o - s)$, and $z = \left(\frac{\mu l}{t}\right)$, equation (17) may be written as $x^2 = (e^x - 1)y + z^2$, which may be recognized to be of the form $f_1(x) = f_2(x) \cdot f_3(y) + f_4(z)$, which is type X of the recognized kinds of equations that can be efficaciously handled by nomographic charts[26]. As developed in Appendix B, our nomographic chart is as given in Figure 16, where great accuracy is obtained in our selected range, as will be demonstrated later. The use of this chart is as explained in connection with Figure 26b which is essentially Figure 16, with additions. Thus to use the chart 16, an index scale or line is utilized that can connect any ordinate on the $\left(\frac{\mu l}{t}\right)^2$-scale with any other on the $2 \alpha \frac{\mu}{t}(s_o - s)$ - scale. These values are determined for any given mill, material being rolled, and reduction contemplated — as will be explained later. The intersection on the curved $\left(\frac{\mu L}{t}\right)$-scale then gives us our desired information. With a little use of the chart, it immediately becomes apparent that there exist certain characteristics of unique importance. Any arbitrary index line drawn yields, in general, two intersection points on the curved scale — and hence two values of $\left(\frac{\mu L}{t}\right)$. As explained in Part I, the lesser of the two values is always used, as the greater represents an imaginary rolling condition, wherein the roll is deformed more than the strip. If now, such an index line goes through the zero point of the y-scale (pt A), we realize that this condition is one of rolling an extremely soft material, of essentially zero rolling resistance, and we would then expect, of course, no roll flattening, i.e., $L = l$, or $\left(\frac{\mu L}{t}\right) = \left(\frac{\mu l}{t}\right)$. An inspection of the chart shows this to be the case — indeed it represents a check on the accuracy of the chart as made. If now, on the other hand, the index line goes through the zero point of the x-scale (or rather, x^2-scale) i.e. through point C, this condition is one of zero reduction — and the important condition "limit of rollability" is given by the index line of steepest slope still intersecting all scales. This condition is given by the critical slope line just tangent to the x-scale at $\left(\frac{\mu L}{t}\right)_{crit} = 1.594$, which intersects the y-scale at 0.647. This latter point is indeed the maximum value of $2 \alpha \frac{\mu}{t}(s_o - s)$ possible, and represents the fact that there is a minimum thickness that can be rolled of

$$2a \frac{\mu}{t_{min}}(s_o - s) = 0.647, \text{ or}$$

$$t_{min} = 3.58 \frac{D\mu(s_o - s)}{E}, \text{ which is our important relationship, established earlier.}$$

For values of $\left(\frac{\mu L}{t}\right)$ greater than 1.594, it is possible to have only one intersection point on the x-scale, namely the tangent — and the values of y and z corresponding to these tangency points represent the maximum reductions possible under the given mill and strip conditions. In fact, they are the points given by the envelope curve in Figures 24 and 25, Appendix A. It is worth mentioning here that associated values of PMF (to $\frac{\mu L}{t}$) could also

be plotted on the x-scale, but it is preferred to retain the simplicity of the chart, as is, and use Figure 4 or a table.

Proceeding further, now, in the development of pertinent formulas, equation (16) may be transposed to solve for the important quantity, $\bar{p}$, which is the actual specific rolling pressure

$$\bar{p}=\frac{\left(\frac{\mu L}{t}\right)^2-\left(\frac{\mu l}{t}\right)^2}{2\left(\frac{\mu L}{t}\right)\left(\frac{\mu a}{t}\right)}=\frac{L^2-l^2}{2aL} \qquad \ldots\ldots\ldots\ldots\ldots (18)$$

whence $P'=\bar{p}L$ and $P=w\bar{p}L$ are directly obtained, as defined in Part I. To obtain the rolling torque, i.e. the torque required to create the rolling pressure, P, let us refer back to equation (8) and Figure 3, where $T_r=2P\left(x_2-\frac{L}{2}\right)$ — but it is also to be realized that the moment arm is also equal to $\left(\frac{L}{2}-x_o\right)$, where $x_o=a\bar{p}$ as shown in equation (7).
Hence

$$T_r=2P\left(\frac{L}{2}-x_o\right)=2P\left(\frac{L}{2}-a\bar{p}\right) \ldots\ldots\ldots\ldots (19)$$

and substituting (18) in (19), we get that

$$T_r=2P\left\{\frac{L}{2}-a\left(\frac{L^2-l^2}{2aL}\right)\right\}=\frac{P\,l^2}{L} \qquad \text{, or}$$

$$T_r=w\,\bar{p}\,l^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

which is indeed a simple and revealing expression for the rolling torque. This expression can be written alternately as $T_r=w\bar{p}\,R\,(t_1-t_2)$, thus relating the pressure $\bar{p}$ and the reduction (t_1-t_2) to the torque required. In the case where there is no strip tension (such as when rolling sheet lengths), or when the front and back tensions are equal, then the above value of torque must be exerted by the mill spindles. In the more general case, however, the mill is assisted in setting up the rolling torque by virtue of more front pull than back pull. This is generally expressed as

$T_{mill}+T_{strip}=T_{rolling}$. Now $T_{strip}\ (T_s)=(S_2-S_1)\,R$, where S_1 and S_2 are the entry and delivery pulls or tensions, and are respectively

$$S_1=w\,s_1\,t_1 \text{ and } S_2=w\,s_2\,t_2$$

where s_1 and s_2 are the tension stresses in psi. Since from the design point of view, we are interested in mill or spindle torque (T_m), we have that

$$T_m=T_r-T_s=w\,\bar{p}\,l^2-(S_2-S_1)\,R, \text{ or}$$

$$T_m=wR\left[\bar{p}\,(t_1-t_2)-(s_2\,t_2-s_1\,t_1)\right] \ldots\ldots (21)$$

In a calculation procedure, while $\bar{p}$ can be calculated from equation (18) once $\left(\frac{\mu L}{t}\right)$ has been determined, it is more readily obtained from equation (9a) by use of the basic curve in Figure 4, where $\bar{p}=(s_o-s)\times PMF$, PMF being given explicity as a function of $\left(\frac{\mu L}{t}\right)$.

Another important quantity that it is desirable to bring into our calculation procedure is hp-hr per ton, since it is this quantity that is more usually obtained in simple tests — as shown in Figure 13. As we shall show, however, this quantity is not solely a function of the material being rolled and the reduction, as is commonly assumed,[27] but is definitely and considerably influenced by work roll size, speed of rolling (bite friction), etc. In general, of course, mill horsepower is given by $HP_m=\frac{T_m\,N}{63{,}000}$, and if it is taken that delivery strip speed equals the roll surface speed, which is correct enough for these calculations, i.e. $V\simeq\frac{2\pi R}{12}\times N$, then we have:

$$HP_m=\frac{T_m\,V}{33{,}000\,R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

where N = work roll (RPM)
V = strip speed (FPM)

Combining (22) and (21), we get

$$HP_m=\frac{wV\left[\bar{p}\,(t_1-t_2)-(s_2\,t_2-s_1\,t_1)\right]}{33{,}000} \ldots\ldots\ldots (23)$$

Since the reels also contribute power to the rolling operation, we must evaluate their influence, as well. Now

$$HP_{reels}=\frac{S_2\,V-S_1\,V_1}{33{,}000}=\frac{S_2\,V-S_1\left(\frac{t_2}{t_1}V\right)}{33{,}000}$$

$$=\frac{Vw\,t_2\,(s_2-s_1)}{33{,}000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Since $HP_{total}=HP_{mill}+HP_{reels}$, our combined expression becomes, by adding equations (23) and (24):

$$HP_{total}=\frac{wV\left[\bar{p}\,(t_1-t_2)-(s_2\,t_2-s_1\,t_1)+t_2\,(s_2-s_1)\right]}{33{,}000}$$

$$=\frac{wV\left[\bar{p}\,(t_1-t_2)+s_1\,(t_1-t_2)\right]}{33{,}000}, \text{ or}$$

$$HP_{total}=\frac{wV\,(\bar{p}+s_1)\,(t_1-t_2)}{33{,}000} \ldots\ldots\ldots\ldots (25)$$

which is a simplified expression, indeed. The fact that the front tension s_2 does not appear explicitly in the expression (25) must not be interpreted to mean that it has no effect on the total power to produce a certain reduction — as it affects the value of $\bar{p}$ considerably, and through it, makes its influence felt.

Now, as to tons per hr of delivered strip, we have (for steel):

$$\text{Tons per hr}=\frac{wV\,t_2\times 12\times 60\times 0.283}{2000}$$

$$=\frac{wV\,t_2}{9.9} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

and combining (25) and (26), we obtain as the energy per unit weight to make a given reduction

$$\frac{\text{hp-hr}}{\text{ton}}=\frac{(\bar{p}+s_1)\left(\frac{t_1-t_2}{t_2}\right)}{3330} \ldots\ldots\ldots\ldots\ldots\ldots (27)$$

7 & 53" x 42"
0/500 F.P.M.

(W = 30") 600 HP 600 HP 600 HP 600 HP

$S_{MAX.} = 40{,}000^{\#}$ - REEL LIMITATION
$P' = \bar{p}L = 53{,}000^{\#}/\text{IN.}$ - CONTACT STRESS LIMITATION
$P\,(\text{TOTAL}) = 2{,}000{,}000^{\#}$ - BACK-UP BEARING LIMITATION
$T_{MILL} = 277{,}000^{\#}\text{ IN.}$ - MOTOR TORQUE NOMINAL MAXIMUM

$2a = \frac{16(1-\nu^2)R}{\pi E} = .54 \times 10^{-6}$

$T_m = 105\,[\bar{p}\,(t_1 - t_2) - (s_2 t_2 - s_1 t_1)]$

$\frac{HP_{roll\ HRS.}}{TON} = \frac{(\bar{p} + s_1)\left(\frac{t_1 - t_2}{t_2}\right)}{3330}$

ROLLING 18/8 STAINLESS

PASS NO.	$t_1 - t_2$ INCH	t_1/t_2	RED. %	TOTAL RED. %	$p_{y.s.}$ #/IN.²	$p_{m.y.s.}$ #/IN.²	S_{02} 1.05 $P_{m.y.s.}$	S_1 #/IN.²	S_2 #/IN.²	S #/IN.²	$(S_2 - S)$ #/IN.²	L (IN) $\sqrt{R(t_1-t_2)}$	V (FPM) STRIP SPEED	μ	$\left(\frac{\mu L}{t}\right)$	$\left(\frac{\mu L}{t}\right)^2$	$2\frac{\mu L}{t}(S_2 - S)$	$\left(\frac{\mu L}{t}\right)$	PMF	$(S_2 - S)$ FMF $\bar{p}$ (#/IN²)	L INCH	$P' = \bar{p}L$ #/IN	$P = \bar{p}P'$ #	T_m # IN.	HP_{roll}	$HP_{Brg\ fr}$	$HP_{contact\ loss}$	$\Sigma \frac{HP\ HR}{TON\ cum.}$
0	.125	—	—	—	35,000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	.095	.030	24.0	24.0	125,000	92,000	106,500	0	13,000	6,500	100,000	.335	250	0.09	.265	.070	.044	.220	1.160	116,000	.357	41,000	1,230,000	785,000	965	22	46	14.3
2	.077	.018	19.0	38.5	148,000	137,000	158,000	7,000	17,000	12,000	146,000	.281	400	0.08	.235	.055	.074	.285	1.156	169,000	.306	52,000	1,560,000	252,000	1150	45	73	28.0
3	.063	.014	18.2	49.5	160,000	155,000	180,000	11,000	21,000	16,000	164,000	.221	500	0.07	.218	.048	.088	.280	1.153	189,000	.285	54,000	1,620,000	233,000	1280	60	92	43.0
4	.051	.012	19.0	59.2	176,000	168,000	193,000	21,000	26,000	23,000	172,000	.205	500	0.07	.250	.063	.114	.325	1.178	202,000	.265	54,000	1,620,000	250,000	1220	60	88	60.7
5	.043	.008	15.7	65.5	184,000	180,000	208,000	26,000	31,000	28,500	179,500	.188	500	0.07	.250	.063	.144	.358	1.202	216,000	.240	52,000	1,560,000	182,000	880	57	73	76.2
6	.036	.007	16.3	71.5	191,000	187,500	216,500	31,000	37,000	34,000	181,500	.155	500	0.07	.278	.077	.175	.410	1.235	226,000	.232	52,500	1,575,000	168,000	815	58	71	93.5
7	.030	.006	16.7	75.8	196,500	193,250	223,000	37,000	44,000	40,500	183,500	.145	500	0.07	.308	.095	.209	.475	1.277	233,000	.224	52,500	1,575,000	147,000	735	58	67	112.4
8	.025	.005	16.7	80.0	201,000	198,750	230,000	44,000	50,000	47,000	183,000	.132	500	0.07	.336	.113	.252	.545	1.318	244,000	.214	52,300	1,570,000	135,000	655	58	64	132.7
9	.021	.004	16.0	83.2	205,000	203,000	235,000	50,000	50,000	50,000	185,000	.118	500	0.07	.360	.130	.305	.630	1.395	258,000	.207	53,500	1,650,000	129,000	560	61	62	154.1
10	.0185	.0025	11.9	85.0	207,000	206,000	238,000	50,000	53,000	50,000	188,000	.094	500	0.07	.332	.110	.359	.680	1.434	270,000	.192	52,000	1,650,000	84,000	365	57	53	171.0
11	.0167	.0018	9.8	86.9	208,800	207,900	240,300	50,000	56,000	53,000	190,500	.079	500	0.07	.314	.099	.409	.750	1.488	284,000	.188	53,400	1,600,000	64,000	275	59	52	185.2
12	.0157	.0010	6.0	87.8	210,500	209,800	243,000	50,000	59,000	56,000	193,000	.059	500	0.07	.255	.065	.450	.770	1.510	292,000	.178	52,000	1,560,000	36,000	155	57	46	196.0
13	.0150	.0007	4.5	88.2	211,000	210,800	243,500	50,000	59,000	56,500	193,500	.049	500	0.07	.222	.049	.472	.795	1.524	295,000	.175	52,000	1,560,000	25,000	110	57	45	205.3

Figure 17 — Table gives step-by-step calculation procedure for determining power and torque requirements for a typical rolling mill operation.

The magnitude of horsepower contributed by the reels can be a considerable factor, particularly if s_2 is greater than s_1, as can be evaluated by comparing (24) with (23) for any given rolling condition.

Actually, there are two other factors that must be considered in determining the power requirements for rolling strip: the power to overcome mill bearing friction, and the power absorbed in deforming the rolls at their contact points. The first factor is quite simple and straightforward to determine, once the total rolling pressure, P, is established—but the second requires quite a bit of study, as we shall do later. Let it be said at this point, however, that this factor which has heretofore not been recognized as significant, can account for a large amount of power, particularly when a mill is being forced to roll thin strip, perhaps thinner than the mill is properly designed for.

We are now ready to demonstrate our greatly simplified and improved calculation procedure. Instead of running a duplicate procedure to that shown in Figure 7, we shall carry through a similar one, for an actual rolling schedule —where 0.125 × 30-in. stainless steel strip is being rolled down to 0.015 in. in 13 passes without intermediate anneals on a 7-in. and 53-in. × 42-in. mill, at speeds up to 500 fpm (as limited by the motors available when the mill was converted). We shall describe the calculation procedure step by step, referring to the table in Figure 17—note that the first steps are identical to our earlier trial-and-error method.

1. From the starting thickness t_1, assume the strip can be reduced to t_2.
2. From the yield stress curve, determine the mean yield stress,

$p_{m.y.s.}$ corresponding to $t = \frac{t_1 + t_2}{2}$, as indicated.

3. Multiply by 1.155 because of constrained yield stress phenomenon to obtain corresponding value of

$$s_o = 1.155 p_{m.\,y.\,s.}$$

4. Subtract average of front and back tension stress, $s = \frac{s_1 + s_2}{2}$, based on selected values of both, i.e. form $(s_o - s)$, which has a considerable effect on reducing the required specific pressure, and particularly the roll flattening effect.

5. List the value of $l = \sqrt{R\ (t_1 - t_2)}$, where l = contact length of unflattened roll.

6. List the value of V = FPM of the strip being rolled, for the particular pass under consideration, and in the adjoining column, list the corresponding value of roll bite friction, μ, (Figure 5).

7. Form the quantity $\left(\frac{\mu l}{t}\right)$, and thence the nomographic chart parameter, $\left(\frac{\mu l}{t}\right)^2$.

8. Form and list the second nomographic chart parameter, $2a\frac{\mu}{t}(s_o - s)$.

9. Now, from the nomographic chart (Figure 16) — for the above values of the parameters — pick off the corresponding value of $\left(\frac{\mu L}{t}\right)$. This step represents the great saving in time and tedium, in that no trial-and-error procedure is required to obtain this important quantity.

10. List the quantity PMF — from curve (Figure 4) or table, as a function of $\left(\frac{\mu L}{t}\right)$.

11. List the value of $\bar{p}$, which is given by $(s_o - s) \times$ PMF.

12. Calculate and list the value of L, from the established value of $\left(\frac{\mu L}{t}\right)$ under item 9.

13. List the values of $P' = \bar{p}L$ and $P = w\bar{p}L$ — these values must be within the limits set by the contact stress between work and backing rolls and/or the capacity of the back-up roll bearings.

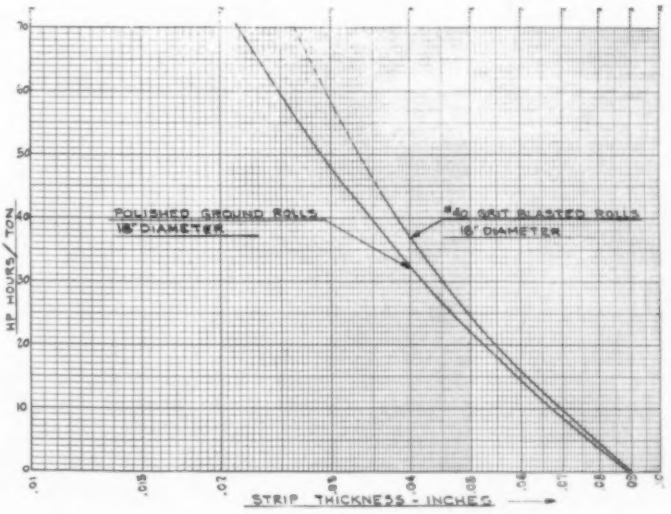
14. In the next two adjoining columns, list the values of mill torque, T_m, and hp_m-hr per ton — quantities given by equations (21) and (27) — required to roll or plastically deform the strip being rolled. This concludes the calculation procedure having to do with the phenomena existing in the roll bite — leading primarily to the calculation of the all-important rolling pressure, and associated rolling power.

Although there yet remain two more factors that subtract from our available mill power, we now wish to examine and study certain rolling phenomena more or less directly related to work roll diameter. Actually it is the effect of work roll diameter on the rolling pressure, through the action of the $\left(\frac{\mu L}{t}\right)$-effect, with which we shall concern ourselves. In fact, any significant factor that reduces $\left(\frac{\mu L}{t}\right)$ will reduce the required rolling pressure, and hence the hp-hr per ton to roll. For instance, higher speed of operation effectively reduces μ, and hence the pressure and power to roll. Any improvement in lubricant, which reduces μ, at a given speed, will have a like salutory effect. Conversely, if the work rolls are sand-blasted or acid-etched as they are occasionally done, μ will increase, and hence through the $\left(\frac{\mu L}{t}\right)$-effect, the required rolling pressure and power will also go up. Figure 18 shows experimental data when rolling thin strip, with both smooth and rough rolls — indicating a 10 per cent increase for the rough rolls.

The role of work roll diameter, D, makes itself felt through the factor, L, in the $\left(\frac{\mu L}{t}\right)$ quantity. Any increase in L for a given reduction, just as any comparable increase in μ, should and does result in increased pressure and power to roll. And, of course, the effect is greatly increased when the factor, t, is small, i.e. when rolling thin material — for we must keep in mind that the pressure is increased exponentially with an increase in the parameter, $\left(\frac{\mu L}{t}\right)$, no matter what the cause.

We wish now to offer evidence, both calculation-wise and test-wise — to show that the required power (and pressure) may be more than 100 per cent higher for larger work rolls than for smaller work rolls — in many cases; and for other cases, a like increase may cause practically no increase in required power. It is probably this latter condition that has caused so many rolling

Figure 18 — Experimental data shows that about a 10 per cent increase in power is required with rough rolls.



mill engineers to have erroneously concluded that work roll size does not affect hp-hr per ton.

Let us take, as a prime example, the cold rolling of stainless steel. In Figure 19, we have assembled test data when rolling from the annealed state, at a starting thickness of 0.125 in. down to a final thickness of 0.060 in., first, as it was done years ago on old mills having work roll diameters from 16 to 20 in.; second, on a 16 in. and 49-in. × 42-in. mill; thirdly, on a 11-in. and 36-in. × 28-in. mill; and finally on an 8-in. and

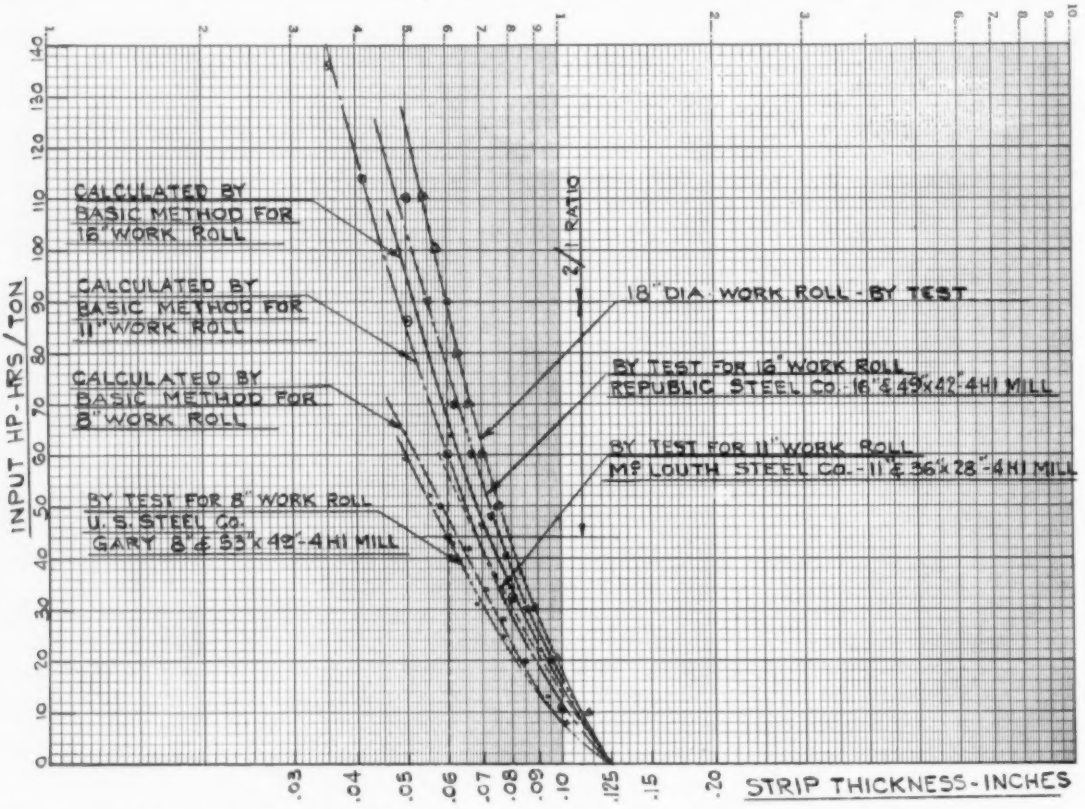

INPUT HP-HRS/TON
STRIP THICKNESS-INCHES
CALCULATED BY BASIC METHOD FOR 16" WORK ROLL
CALCULATED BY BASIC METHOD FOR 11" WORK ROLL
CALCULATED BY BASIC METHOD FOR 8" WORK ROLL
2/1 RATIO
18" DIA. WORK ROLL - BY TEST
BY TEST FOR 16" WORK ROLL REPUBLIC STEEL CO. 16" & 49" x 42" - 4 HI MILL
BY TEST FOR 11" WORK ROLL Mt. LOUTH STEEL CO. - 11" & 36" x 28" - 4 HI MILL
BY TEST FOR 8" WORK ROLL U. S. STEEL CO. GARY 8" & 53" x 49" - 4 HI MILL

Figure 19 — Curves give test and calculated data for cold rolling 18-8 stainless for various work rolls diameters.

53-in. × 49-in. mill. In the old days, it used to be figured that 90 hp-hr per ton were required for this operation — but on the recent smaller work roll mill, back-up driven, the tests show that only 44 hp-hr per ton are required — less than half! Tests on other mills having intermediate size work rolls, show an intermediate decrease — from which it is apparent that on a modern mill for this product, only half the mill motors need be used that were originally required, with corresponding decrease in first costs all round, as well as operating costs. To show how what we have termed our "basic" method of calculation would predict this same trend, E. A. Randich carried through a series of calculations, similar to that exhibited in Figure 17, and the results plotted on the same graph. It is to be pointed out that the primary factor that is varied, with work roll diameter, is the Pressure Multiplication Factor (PMF), which affects the value of $\bar{p}$ directly, and hence the hp-hr per ton — see equation (27). In this equation, the factor that varies with work roll diameter is

$$(\bar{p} + s_1) \text{ — actually, } (\bar{p} + s_1) = \left(s_0 - \frac{s_1 + s_2}{2}\right)$$

$\times$ PMF $+ s_1$. For a 50 per cent reduction, from $t_1 =$ 0.125 in. to $t_2 = 0.060$ in., a proper value of s_0 is 180,000 psi, and average values of s_1 and s_2 are about 20,000 psi each. The lowest possible value for PMF is, of course, 1.00; and a usual high value is 2.00, or more. By carrying through the indicated arithmetic, it is easily seen that the ratio of energies in this case is 11.1 hp-hr per ton to 5.9 hp-hr per ton = 1.89 i.e., an 89 per cent increase.

For other materials, such as titanium and its alloys, the variation in hp-hr per ton with roll size is even greater — reaching over a 200 per cent increase. The reason for this fact is that although the basic deformation resistance of these materials, $p_{m.y.s.}$ is lower than for the stainless steels in the work hardened state, the coefficient of friction between the titanium strip and the steel work rolls is much higher than for stainless strip — the net result being that titanium is much more difficult to roll, as is well known. By the same token, then, a decrease in work roll diameter has a proportionately larger effect on decreasing the power (and pressure) to roll — and is the reason why the mill shown in Figure 15 has provisions for small work rolls. On the other hand, for materials that are easy to roll, i.e., materials having a low deformation resistance, with reasonable work hardening properties, and with low friction coefficients, the effect of work roll size is smaller — as is both predicted by theory, and substantiated by tests. Thus for low carbon steel, such as tinplate, etc., for copper and its alloys, and particularly for aluminum, it may be said that the advantages of small work rolls are overshadowed by their disadvantages, such as increased wear, more frequent roll changes, etc. To illustrate this latter fact, Figure 20 shows test data when rolling soft aluminum, 2S, with a large work roll, on a 15-in. and 33-in. × 58-in. mill — and also are shown predicted energy requirements (by the basic method herein described) for a 3-in. diam work roll — the coincidence is remarkable, showing that for such soft materials, a small work roll is of no advantage whatsoever.

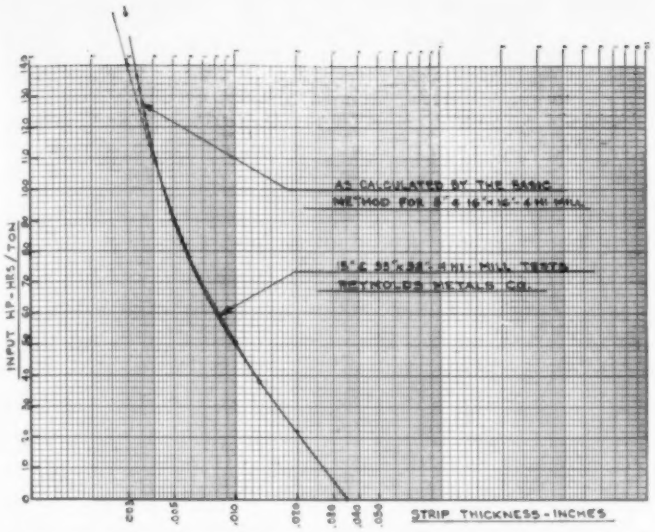

AS CALCULATED BY THE BASIC METHOD FOR 5" & 16" H.S. 4 HI MILL
5" & 32" x 36" 4 HI MILL TESTS REYNOLDS METALS CO.
INPUT HP-HRS/TON
STRIP THICKNESS-INCHES

Figure 20 — Cold roll test on soft aluminum shows little difference in power required using 20-in. diam work roll compared with that predicted for the 3-in. diam work roll.

Now, let us return to two factors mentioned earlier — mill bearing friction and work roll-backup roll contact energy loss. Due to the rolling pressure, P, there exists a tangential force $\mu_{brg.} \times P$ acting at the backup bearing radius R_{brg}, so that the friction hp of both backup bearings (in a 4-high mill) is given by

$$HP_{\text{bearing friction}} = \frac{2 \times \mu_{brg} \; P \times R_{brg} \times 2\pi \; N_{BU}}{12 \times 33{,}000},$$

which can be transformed into

$$HP_{bf} = \frac{\mu_{brg} \; P \left(\frac{R_{brg}}{R_{BU}}\right) V}{16{,}500} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (28)$$

To convert to hp_{bf}-hr per ton, we combine equations (28) and (26), to get finally

$$hp_{bf}\text{-hr per ton} = 5.95\left(\frac{\mu_{brg}}{t_2}\right)\left(\frac{R_{brg}}{R_{BU}}\right)P' \times 10^{-4} \ldots\ldots (29)$$

To get some idea of the magnitude of this quantity, let us say we were rolling stainless steel down to 0.020 in. The value of P′ might reach 100,000 lb per in. of width, μ_{brg} 0.002 (for good low friction bearings), the ratio $\frac{R_{brg}}{R_{BU}}$ 0.60, so that hp_{bf}-hr per ton would be of the order of 3.6 hp-hr per ton for this pass. While this is not large compared with the deformation energy — which might be, say, 20 hp-hr per ton for this pass — if however we were attempting to roll down to say 0.010 in., then the hp_{bf}-hr per ton would be around 7.2, and the deformation energy around 4, so that in this realm, the bearing friction loss becomes relatively large.

Now, as to energy lost or absorbed in the contact stress area between the work rolls and back-up rolls, this factor has always been neglected in rolling mill calculations, but certain experiences that will be recounted later, when attempting to roll down to thin gauges on fairly large work roll mills, called this matter forcibly to our attention. As we have analyzed the matter, the conditions that exist between back-up rolls and work rolls, giving rise to "rolling friction," come about because of the flattening of the rolls at their contact point, coupled with the phenomenon of imperfect elasticity. This matter of rolling friction was first studied by Coulomb in 1781 — who also gave us our first law of sliding friction — in connection with studies of wheel friction in artillery vehicles. The result of his experiments was expressed as

$$\left.\begin{aligned} T &= f\frac{P}{R} \\ \text{or } \frac{T}{P} &= \mu = \frac{f}{R} \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (30)$$

(Coulomb)

In Coulomb's work, f was an abstract factor, being a function of the materials only — see Figure 21a. By introducing the ratio of the tangential force to the vertical force, and calling it μ, the "coefficient of rolling friction," similar to what he introduced (and we still use today) for the evaluation of sliding friction, we see that Coulomb's law stated that μ is inversely proportional to the radius of the wheel or roller. Some fifty years later, another Frenchman, M. Dupuit, described results of a more carefully carried out series of tests[28],

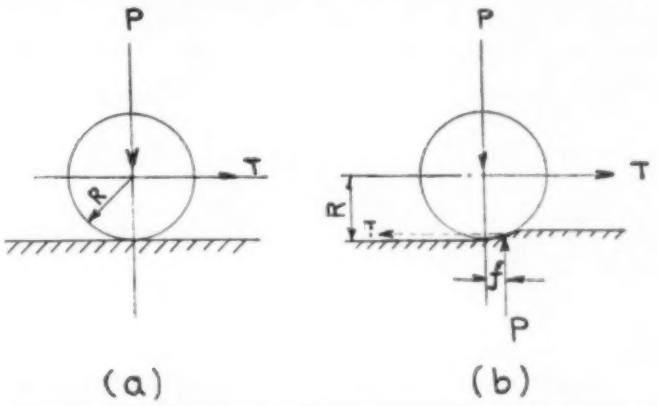


Figure 21 — Sketch at left illustrates Coulomb's law of rolling friction and that on right illustrates Dupuit's law of rolling friction.

wherein he took issue with Coulomb. From the diagram in Figure 21b, illustrating Dupuit's ideas, we see that equilibrium of forces and moments leads to $TR = Pf$, or $T = f\frac{P}{R}$, which is the same expression as Coulomb's.

However, Dupuit recognized that f represented a distance or "arm" (and was not an abstract factor) — and stated further that f was proportional to the square root of R, i.e.

$$\left.\begin{aligned} f &= k\sqrt{R} \\ \text{and} \quad T &= f\frac{P}{R} = k\frac{P}{\sqrt{R}} \\ \text{and} \quad \frac{T}{P} &= \mu = \frac{k}{\sqrt{R}} \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (31)$$

(Dupuit)

which states that the coefficient of rolling friction, μ, is inversely proportional to the square root of the radius

of the roller. Dupuit went even further in discussing the origin of the arm, f, stating that it is due to the deformation of the materials at the contact point — and that if the wheel or roller were rolling on another roller, instead of on a plane, that $f \propto \sqrt{\frac{R_1 R_2}{R_1 + R_2}}$, which in a sense antidated some of Hertz's more thorough and profound conclusions about contact stresses and deformations published in 1881. Dupuit went still further, and recognized that the arm f in Figure 21b, was off center from the centerline of the roller, and ascribed this fact to what he called the "imperfect elasticity" of the material in that as the roller moved along, the material of the plane on which the roller moved did not elastically follow up behind the moving roller, hence giving rise to the non-symmetrical deformation condition. About this time, however, the prominent military engineer, General A. Morin, took up the study of

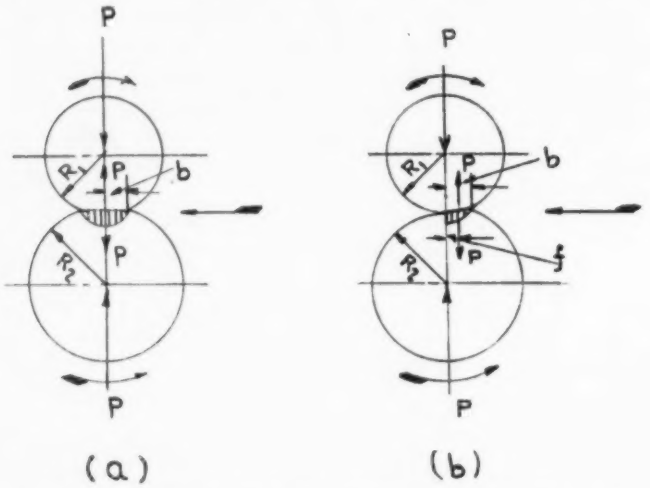


Figure 22 — Sketch on left illustrates a perfect elastic contact stress condition between two rolls according to Hertz for materials which obey Hooke's law. Sketch on right illustrates imperfect elastic contact stress conditions.

friction again, and confirmed Coulomb's earlier work on both sliding and rolling friction. This precipitated a running debate before the French Academy, and sad to relate, a commission set up for the purpose, ruled that Coulomb's (and Morin's) law was the more correct. The present author would like to call attention hereby to Dupuit's work, and give it the recognition it deserves, even though it does not cover the subject completely, as we shall see. For instance, Dupuit still thought that his k was a function of materials only, and not a function of the load, P, as well.

In 1876, in an attempt to further study the matter of rolling friction, O. Reynolds, the eminent engineer and pioneer in the theory of bearing lubrication, reconfirmed Coulomb's law, and ascribed the energy loss in rolling friction (incorrectly, as we shall show) to micro-slippage in the contact area. In 1894, Crandell[29], in carrying out an experimental study of friction rollers used in drawbridge construction, confirmed Dupuit's earlier work, and accurately established a series of rolling coefficients. He also, however, failed to establish that the coefficients were a function of load, as well as $\frac{1}{\sqrt{R}}$, the materials, etc. In 1921, Whittemore and Petrenko[30] carried out what is probably the most accurate experimental work on ball and roller friction, and established for the first time that the coefficient of rolling friction also increases with the load, and from an examination of their Figure 12, this writer would conclude that $\mu \propto \sqrt{P}$ would be as reasonable an approximation as any. Combining Dupuit's and Whittemore's results, we have that

$$\left.\begin{aligned} \mu = k\sqrt{\frac{P}{R}} = \frac{T}{P} = \frac{f}{R} \\ \text{or} \quad f = k\sqrt{PR} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (32)$$

The analogy between this expression for the arm, f, and Hertz's expression for the semi-flattened length, b, in Figure 22a is now apparent, since:

$$\left.\begin{aligned} b = 1.52\sqrt{\frac{P}{wE}\left(\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}\right)} \text{ (generally)*} \\ \text{or } b = \frac{1.52}{\sqrt{wE}}\sqrt{PR} = k'\sqrt{PR} \\ \text{for } R_2 = \infty,\ R_1 = R, \text{ and } k' = \frac{1.52}{\sqrt{wE}} \end{aligned}\right\} \quad \ldots\ldots (33)$$

This similarity led Fromm[31], based on earlier inaccurate attempts by Fuchs, Lechner, etc., to correctly analyze the mechanics of rolling friction. The same result is more simply obtained, however, by considering Figure 22b. Here we assume that as the rolls rotate, under a pressure P, the contact pressure builds up according to Hertz, but that after the centerline is passed, the roll material does not spring back fast enough, resulting in what we term a totally imperfect elastic contact stress condition. Under these conditions, the contact width, b, is larger than for Figure 21a (where the load P is carried centrally by a total contact width of 2b), and is given by

$$b = 2.15\sqrt{\frac{P}{wE}\left(\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}\right)} \quad \ldots\ldots\ldots\ldots (34)$$

The contact pressure distribution is a semi-elliptic one*, given by

$$\left.\begin{aligned} p = \frac{4}{\pi}\frac{P}{wb^2}\sqrt{b^2 - x^2} \\ \text{and } p_{ave} = \frac{P}{wb} = 0.47\sqrt{\frac{P}{w}E\left(\frac{1}{R_1} + \frac{1}{R_2}\right)} \end{aligned}\right\} \quad \ldots\ldots (35)$$

Now the resultant of the pressure distribution occurs at some distance, f, away from the centerline, evaluated by

*See, for instance, Theory of Elasticity, by Timoshenko and Goodier, 2nd edition, p 381-382.

$$f = \frac{\int_0^b p\,x\,dx}{\int_0^b p\,dx} = \frac{4}{3\pi}\,b \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (36)$$

obtained by substituting in the expression for p from (35a). The resistance torque therefore, of each roll against turning (they are equal) is Pf, and the horsepower required to turn the rolls is

$$HP_{loss} = \frac{2\pi T_1 N_1}{33{,}000} + \frac{2\pi T_2 N_2}{33{,}000} = \frac{2\pi}{33{,}000}\left[T_1 N_1 + T_2 N_2\right]$$

$$= \frac{2\pi}{33{,}000} \times \frac{Pf}{12}\left\{\frac{V}{2\pi R_1/12} + \frac{V}{2\pi R_2/12}\right\}$$

$$= P\,Vf\left(\frac{1}{R_1} + \frac{1}{R_2}\right).$$ Substituting in the value of f, from (36), we get finally

$$HP_{loss} = \frac{P\,V\,\frac{4}{3\pi}\,b\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}{33{,}000} \qquad \ldots\ldots\ldots\ldots (37)$$

In the above equations, w = length of roll body under pressure (in.), E = modulus of elasticity, psi, T_1 and T_2 the torques on each roll in ft-lb, N_1 and N_2 the rpm of each of the rolls, and V the surface speed of the rolls in fpm. The expression given above is for totally imperfect elastic condition; for perfectly elastic conditions (Figure 22a — arm = 0) the horsepower loss is, of course, zero. In actual practice, depending on the type of materials, the contact conditions, the speed of rolling, etc., we expect the loss to be represented by

$$HP_{loss} = \alpha\frac{P\,V\,\frac{4}{3\pi}\,b\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}{33{,}000} \qquad \ldots\ldots\ldots\ldots (38)$$

where α is a coefficient < 1, and is similar to the elastic hysteresis loss coefficient for metals.

Substituting (34) in (38), we get:

$$HP_{loss} = \alpha\frac{0.92\,V\sqrt{\frac{1}{wE}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}}{33{,}000}\,P^{\frac{3}{2}}$$, or

$$\frac{HP_{loss}}{w} = \alpha\frac{0.92\,V\sqrt{\frac{1}{E}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}}{33{,}000}\left(\frac{P}{w}\right)^{\frac{3}{2}} \qquad \ldots\ldots (39)$$

from which we see that the horsepower loss per unit of width is proportional to the $\frac{3}{2}$ power of the load per unit width, i.e. $\frac{HP_{loss}}{w} \propto P^{\frac{3}{2}}$. This relationship, however, is true only as long as Hooke's law holds, which is the condition we have discussed thus far. In this range, we see from (34) that $b \propto \sqrt{P}$, and that p_{ave} is also $\propto \sqrt{P}$ — from (35b). However, as P is increased, and p_{ave} exceeds the yield stress of the materials, roll flattening takes place at an increasing rate, until when p_{ave} approaches 3 × yield stress, b becomes linearly proportional to P ($b \propto P$), and p_{ave} levels off around the three times the yield stress value — see Tabor[32]. At this later stage, the HP_{loss} increases much faster with P, and the relationship $HP_{loss} \propto P^2$ is more nearly true, modified by an increasing coefficient α, which also increases rapidly when the yield stress is exceeded. It is to be expected, therefore, that in this range HP_{loss} may increase with a power considerably greater than 2, possibly 3 or more.

The above relationships show what happens on a given mill, as the roll pressure is increased. To see, now, how the contact losses vary from mill to mill, especially as a function of work roll diameter, we introduce p_{ave} from equation (35b) into (39), and get

$$\frac{HP_{loss}}{w} = \alpha\frac{8.9\,p_{ave}^{2}\,V}{33{,}000\,E^2\left(\frac{1}{R_1} + \frac{1}{R_2}\right)^3}$$

$$\text{or} = \alpha\frac{8.9\,p_{ave}^{2}\,V}{33{,}000\,E^2\left(1 + \frac{R_1}{R_2}\right)^3}R_1^3 \qquad \ldots\ldots\ldots (40)$$

Now, for the usual 4-high mill, $R_1 < R_2$ — and since mills are usually designed for a uniform limiting contact stress between work roll and back-up roll (p_{ave}), we see that the contact loss varies approximately as the cube of the work roll size. For a mill having a 56-in. diam back-up roll and a 16-in. diam work roll, the losses will be about 12 times greater than for a 6-in. diam work roll mill.

And now to return to an appreciation of the actual magnitudes of the losses that we are concerned with. Some years ago, we were called in by a steel plant regarding the possibility of cold rolling stainless steel strip, 37½ in. wide, from 0.090 in. to 0.018 in., full hard — on a 15¼-in. and 49-in. × 42-in. mill, driven by a 1500-hp motor, 0/600/1200 fpm. As the final gage was being approached, it became apparent that dozens of passes would be required, if the final gage could be reached at all (without annealing, of course) as the t_{min} for the mill (equation 12) was practically the final gage required. The mill was equipped with bearings and adequate back-up roll necks to withstand a rolling pressure of 5,000,000 lb. As the final gage was being approached, and essentially no reduction was being accomplished, the screws were operated to increase the pressure — and to our amazement, the power drawn from the mill motor, at its base speed, approached 50 per cent overload at the maximum pressure — and still no reduction! Where was the power going? The strip was then removed from the mill, and a series of tests run at various pressures and speeds. Figure 23 shows one of these tests, with calculated figures based on equations (28) and (39) for comparison purposes. The first part of the test curve — up to a mill pressure of 2,000,000 lb, corresponding to an average contact pres-

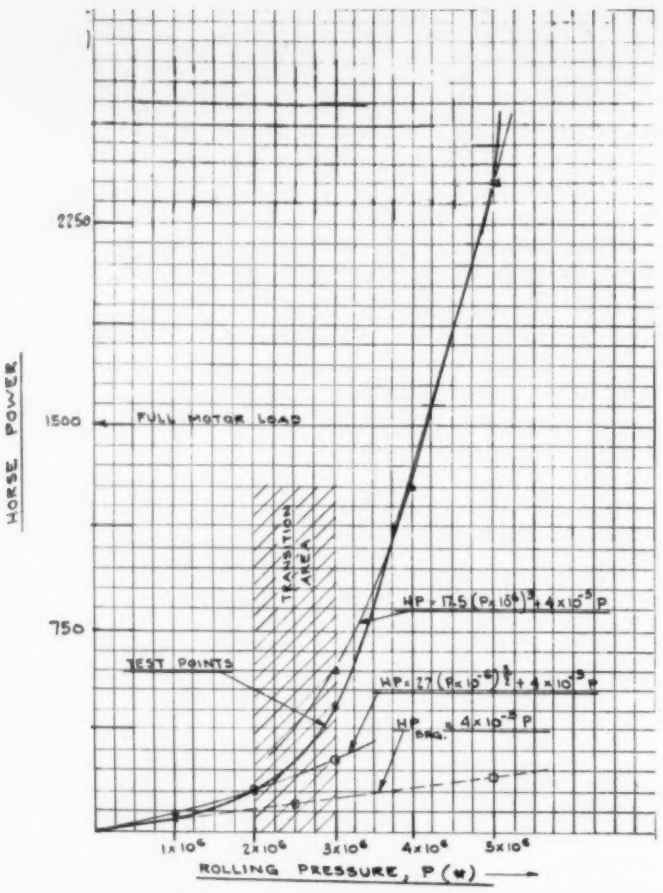


Figure 23 — Data is given for idle power versus pressure tests on a 15¼ and 49 x 42-in., 4-high mill with no strip in mill and speed of 600 fpm. Drive is 1500 hp, 0/600/120 fpm.

sure of 250,000 psi between back-up rolls and work rolls, and a pressure of 300,000 psi between the work rolls — is closely approximated by equation (39), with $\alpha = 0.04$ (4 per cent). The second part of the curve is closely approximated by a curve $HP_{loss} = k\ P^3$. The transition zone corresponds to a back-up roll contact pressure of around 275,000 psi — which is about 3 × yield stress — and shows that in the "plastic" range, the power losses rise precipitously, with concurrent serious consequences to roll life, as well. Similar occurrences have been observed, at times, on large work roll skin pass mills for tin plate (dry rolling) where back-up rolls have actually turned blue due to surface temperature increases undoubtedly caused by hysteresis losses, such as described herein.

The primary point that we wish to make in this general regard is that large power losses can be accounted for and explained by an appreciation of "rolling friction" conditions between the mill rolls in contact, especially when the contact stress passes the approximate value of 3 × yield stress of the roll materials. A second point of considerable importance is that these losses are greatly reduced when smaller work rolls are used — roughly as the cube of the work roll diameter. More recently, D. Tabor[33] has undertaken a thorough study of the mechanism of rolling friction, with particular emphasis on ball bearings, and has underlined the argument that " the major part of the resistance to rolling arises from the elastic hysteresis losses in the metals themselves." It is to be hoped that Tabor will continue his research, using rollers (or even an experimental rolling mill) to establish more fully the limits of the domain indicated in Figure 23, and the like.

This thesis is now completed. The methods outlined above enable us to predict the mill pressures and powers required for the rolling of metals, starting with certain fundamental data — and recognizing the various limiting considerations that are encountered in rolling. While the factors cited apply equally as well to hot rolling, and also to the cold rolling of thick strip — as the considerations are basic — the errors made in using simpler methods do not result in misleading conclusions in such cases, as they do for the rolling of thin strip. Hence do we feel that the methods described in these two papers are justified, and form a basis for the understanding of the phenomena associated with the rolling of thin strip and provide criteria for the designing of mills for its most efficacious accomplishment.

APPENDIX A — FAMILY-OF-CURVES SOLUTION OF ROLL PRESSURE PARAMETER

Equation (17) may be rearranged to read:

$$\left(\frac{\mu l}{t}\right)^2 + 2a\frac{\mu}{t}(s_o - s)\left(e^{\frac{\mu L}{t}} - 1\right) - \left(\frac{\mu L}{t}\right)^2 = 0$$

and calling $z = \left(\frac{\mu l}{t}\right)$, $y = 2a\frac{\mu}{t}(s_o - s)$, and

$\lambda = \left(\frac{\mu L}{t}\right)$, we have

$$z = +\sqrt{\lambda^2 - \left(e^{\lambda} - 1\right)y} \quad \ldots\ldots\ldots\ldots (41)$$

as the type of equation that we wish to plot, for assigned values of λ. From experience, we know that practically λ varies from 0 to 3.50 — and for accuracy in rolling calculations, we should know all relationships for values of λ varying in steps of 0.01. This would mean plotting 350 curves for the range of λ's under study. To advance the matter further, for the purposes of indicating the difficulties without actually getting into them, we have calculated only 7 such curves, corresponding to values of λ of 0, 0.50, 1.00, etc., to 3.50, as shown in Figure 24. For accurate use of such a chart, at least 50 more curves should be plotted between each of those shown, and the confusion of the chart would then become apparent.

However, this method of presentation brings out certain facts and limitations in the rolling of thin strip that are important to observe. From a visual study of the curves in Figure 24, we see that there is an envelope encompassing the area covered by the curves, which area may be called the domain of rollability — outside this envelope, we have the domain of non-rollability. Referring to equation (41) recast, we have

$f = z^2 - \lambda^2 + \left(e^{\lambda} - 1\right)y = 0$. Now the envelope is defined by the above curve $f(y, z, \lambda) = 0$ and $\frac{\partial f}{\partial \lambda}(y, z, \lambda) = 0$. This latter condition gives us

$-2\lambda + e^{\lambda}y = 0$, or $y = \frac{2\lambda}{e^{\lambda}}$. Substituting this expression

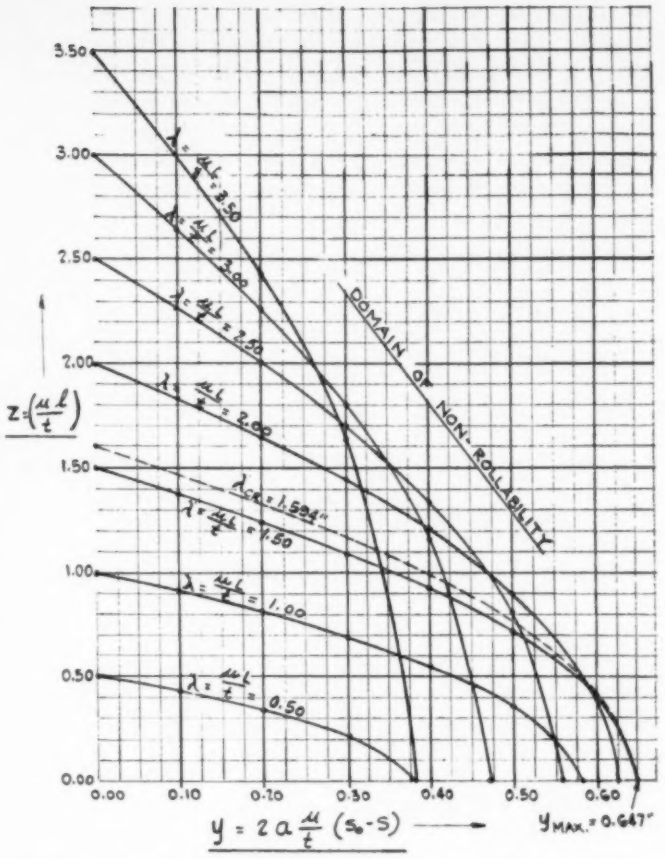

DOMAIN OF NON-ROLLABILITY
$\lambda = \frac{\mu L}{t} = 2.50$
$\lambda = \frac{\mu L}{t} = 2.00$
$\lambda = \frac{\mu L}{t} = 1.50$
$\lambda_{crit} = 1.594$
$\lambda = \frac{\mu L}{t} = 1.00$
$\lambda = \frac{\mu L}{t} = 0.50$
$z = \left(\frac{\mu l}{t}\right)$
$y = 2a\frac{\mu}{t}(s_o - s)$
$y_{MAX.} = 0.647$

Figure 24 — Family of curves develop areas of rollability and non-rollability.

for y in equation (41), and rearranging, we have:

$$z = +\sqrt{\frac{\lambda}{e^{\lambda}}(\lambda e^{\lambda} - 2e^{\lambda} - 2)}, \text{ so that the}$$

equation of the envelope is given by

$$\left.\begin{aligned} y &= \frac{2\lambda}{e^{\lambda}} \\ z &= +\sqrt{\frac{\lambda}{e^{\lambda}}(\lambda e^{\lambda} - 2e^{\lambda} - 2)} \end{aligned}\right\} \quad \ldots\ldots\ldots (42)$$

A plot of the envelope, as given by equation (42) is shown in Figure 25, so as not to confuse Figure 24 too much. Now, we see that z (from equation (42)) is real and positive for values of λ determined by $\lambda e^{\lambda} - 2\,e^{\lambda} - 2 \geq 0$. We solve the foregoing equation, equated to zero, and realize that it is precisely the condition given by equation (11) of part I — and obtain the result that $\lambda_{critical} = 1.594$. This means that the envelope exists for all values of λ greater than 1.594, and furthermore that y is a maximum when $z = 0$, the value of y_{max} being:

$$y_{max} = \left[2\,a\,\frac{\mu}{t}\,(s_o - s)\right]_{max} = \frac{2 \times 1.594}{e^{1.594}} = 0.647 \quad (43)$$

Remembering that

$$a = \frac{8\,(1-\nu^2)}{\pi E} \quad R = \frac{4\,(1-\nu^2)}{\pi}\,\frac{D}{E} = 1.178\,\frac{D}{E},$$

and substituting in (43), we get $2 \times 1.178\,\frac{D}{E} \times \frac{\mu}{t}$ $(s_o - s) = 0.647$, which maximum condition occurs when $t = t_{min}$. Therefore, by transposition, we obtain

$$t_{min} = \frac{2 \times 1.178}{0.647}\,\frac{D}{E}\,\mu\,(s_o - s) = 3.58\,\frac{D\,\mu\,(s_o - s)}{E} \quad (44)$$

which again checks equation (12) of Part I.

APPENDIX B — DEVELOPMENT OF ROLLING PRESSURE NOMOGRAPHIC CHART

Equation (17), as explained in the main body of the paper, can be written as

$$x^2 = (e^x - 1)\,y + z^2, \text{ where}$$

$x = \left(\frac{\mu L}{t}\right)$, $y = 2\,a\,\frac{\mu}{t}\,(s_o - s)$, and $z = \left(\frac{\mu\,l}{t}\right)$ — and is of the form $f_1(x) = f_2(x).\,f_3(y) + f_4(z)$.

To show how such an equation can be represented by a nomographic chart, refer to Figure 26, in which are drawn two vertical straight line scales for the variables z and y, having origins or zero — points at A and C. Now length AB is laid off equal to $m_y.\,f_3(y)$, where m_y is some convenient scale factor introduced to keep the chart within the interested range of values of $f_3(y)$. Likewise, $CD = m_z.\,f_4(z)$. Next the index line DB is drawn. Point F on the x-scale (which, in general, is a curve, for this type of equation) is determined by the two coordinates CE and EF, the first laid off from origin C along the line CA, and EF laid off from point E vertical and parallel to the y- and z-scales. The values of the coordinates are determined by the equations

$$\left.\begin{aligned} CE &= \left[\frac{m_z\ CA}{m_z \times f_2(x) + m_y}\right] f_2(x) \\ EF &= \left[\frac{m_y\ m_z}{m_z\ f_2(x) + m_y}\right] f_1(x) \end{aligned}\right\} \quad \ldots\ldots (45)$$

The locus of all such points, F, establishes the x-scale. The demonstration of the correctness of this procedure may be found in any book on the subject, such as Lipka[26].

Specifically, now, coming to our case

$$\left.\begin{aligned} f_1(x) = x^2 \quad &= \left(\frac{\mu L}{t}\right)^2 \\ f_2(x) = e^x - 1 \quad &= e^{\frac{\mu L}{t}} - 1 \\ f_3(y) = y \quad &= 2\,a\,\frac{\mu}{t}\,(s_o - s) \\ f_4(z) = z^2 \quad &= \left(\frac{\mu\,l}{t}\right)^2 \end{aligned}\right\} \quad \ldots\ldots (46)$$

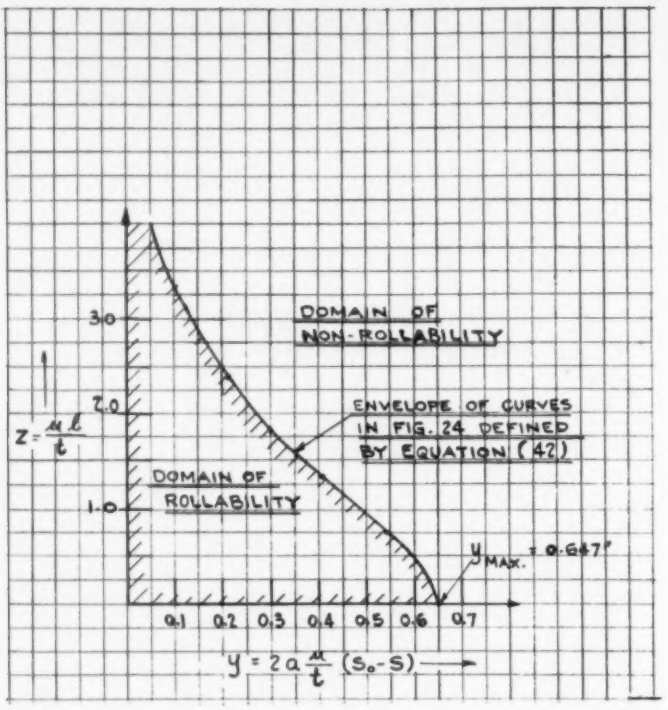


Figure 25 — Sketch shows envelope for curves in Figure 24.

We further choose to have the origin of the y- and z-scales on the same level, i.e., line CA is chosen horizontal. We see further, from the expressions for CE and EF, which in our case become

$$\left.\begin{aligned} CE &= \left[\frac{m_z\ CA}{m_z\ (e^x-1)\ +\ m_y}\right](e^x-1) \\ EF &= \left[\frac{m_z\ m_y}{m_z\ (e^x-1)\ +\ m_y}\right] x^2 \end{aligned}\right\} \quad \ldots\ldots (47)$$

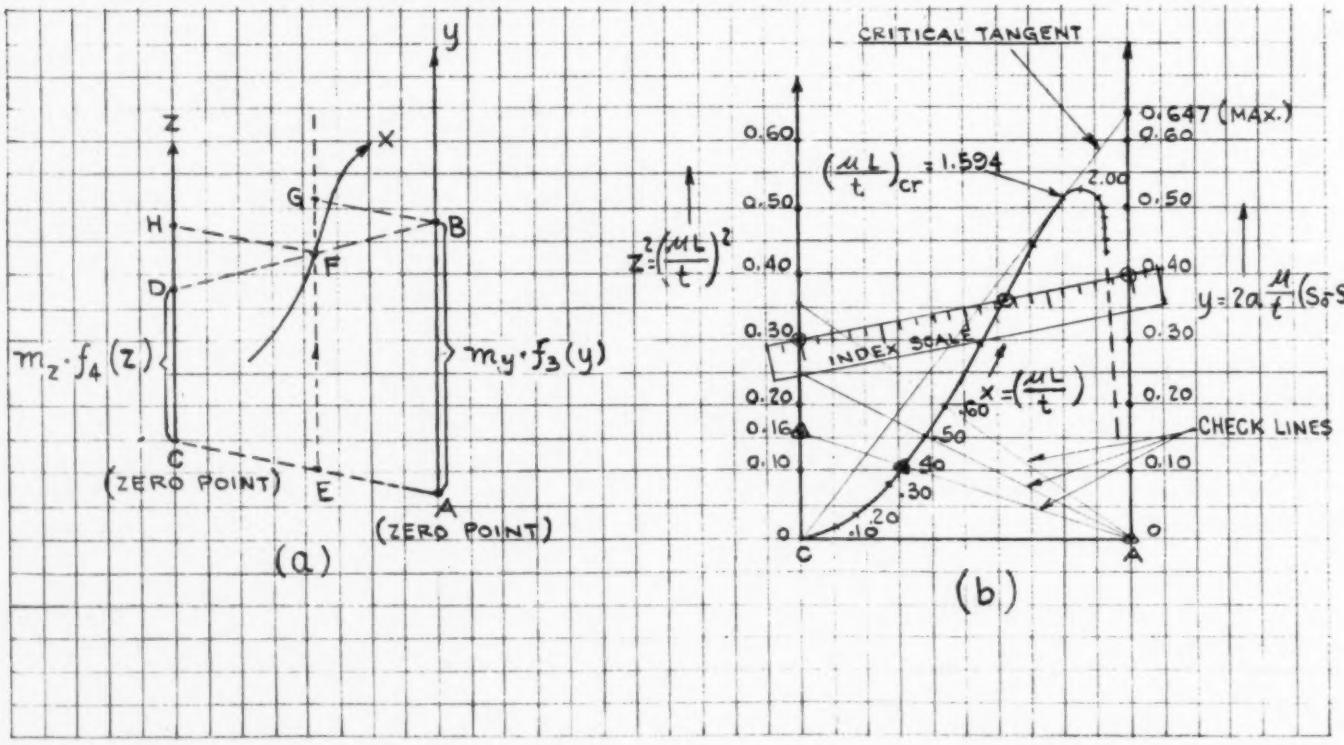
that when $x=0$, $CE=0$, and $EF=0$, i.e. the origin of the x-scale is the same as the origin of the z-scale, namely point C. In selecting the range of variables and scale factors, remembering that $y_{max}=0.647$, we select a chart range for y of 0.60, and choose the same range for z^2, making the range of z from 0 to 0.80. Furthermore, selecting 15 in. for the height of the chart, and 10 in. for the width, i.e. CA = 10 in., we get that $m_z=\frac{15}{0.60}=25$ and $m_y=\frac{15}{0.60}=25$ — leading to

$$\left.\begin{aligned} CE &= \frac{10\ (e^x-1)}{e^x} \\ EF &= \frac{25\ x^2}{e^x} \end{aligned}\right\} \quad \ldots\ldots (48)$$

as the coordinates of the $x=\left(\frac{\mu L}{t}\right)$ - scale. Based on the above, the generic chart of Figure 26a now becomes our specific chart as shown characteristically in Figure 26b, and numerically in Figure 16.

The final $\left(\frac{\mu L}{t}\right)$ - scale is CBA, the correctness and accuracy of which may be checked in several ways. For instance, from equation (17), it is evident that for the condition of rolling a very soft material, the parameter $2a\frac{\mu}{t}(s_o-s)\rightarrow 0$ and $\left(\frac{\mu L}{t}\right)\rightarrow\left(\frac{\mu l}{t}\right)$. This condition is given, chart-wise, by drawing check lines (special cases of the index scale) from $y=0$ at point A, to any point

Figure 26 — Nomographic chart for determining rolling pressures: (a) generic; (b) specific (see Figure 16).



on the $z^2 = \left(\frac{\mu l}{t}\right)^2$-scale—for instance $z^2 = 0.16$. Then we get that $\left(\frac{\mu L}{t}\right) = 0.40$, which when squared = 0.16, as it should. While now, the index scale intercepts the $\left(\frac{\mu L}{t}\right)$-scale at two points, in general, we disregard the second intersection point in the dotted part of the scale, as being irrelevant — the argument here is the same as that given in part I, in connection with discussion of Figure 8.

The important condition of "limit of rollability" (reference Figures 10 and 25) is given here by the index line or scale having the steepest slope possible, and still intersecting all scales. This is shown by the line marked "critical slope" — Figure 26b — where $\left(\frac{\mu l}{t}\right)^2 = 0$ (meaning no reduction, since $l = \sqrt{R\ (t_1 - t_2)} = 0$ is satisfied by $t_1 - t_2 = 0$). From this zero point, C, the slope of any index line is $s = \frac{EF}{CE}$, which becomes by substituting in the expression from equation (48):

$$s = \frac{5\ x^2}{2\ (e^x - 1)} \qquad (49)$$

By seeking the condition $s = s_{max.}$ as a function of x, determined by $\frac{ds}{dx} = 0$, it develops that $x_{cr.} = \left(\frac{\mu L}{t}\right)_{cr} = 1.594$, which is the same result as that given by equation (11), although by a somewhat more devious procedure. The actual value of s_{max}, by substituting in the critical value of $x_{cr.} = 1.594$ in equation (49), gives $s_{max} = 1.61$ — which means that the critical tangent intersects the y-scale at $\frac{1.61 \times 10}{15} \times 0.60 = 0.647$. This, we must appreciate is the maximum possible value of y where rolling can take place, corresponding to the minimum thickness that can be rolled, i.e. $y_{max} = 2\ a\ \frac{\mu}{t_{min}}\ (s_o - s) = 0.647$, or $t_{min} = 3.58\ \frac{D\ \mu\ (s_o - s)}{E}$, which condition we recognize again, as we have previously — equations (12) and (44).

Another interesting check point is the topmost point on the x- or $\left(\frac{\mu L}{t}\right)$-scale. To find this, we write the expression for the tangent to the x-scale, as $\tau = \frac{d\ (EF)}{d\ (CE)} = \frac{d\ (EF)}{dx} \div \frac{d\ (CE)}{dx}$ — from which we get that $\tau = \frac{5x\ (2\text{-}x)}{2}$. And since the maximum point has a horizontal tangent, we get as the maximum point, $x = \left(\frac{\mu L}{t}\right) = 2.00$ — which is checked from an examination of Figure 16. For practical calculations, i.e. from $\left(\frac{\mu L}{t}\right) = 0$ to 3.50, Figure 16 is a carefully prepared nomographic chart, accurate to 0.01. Such a chart should cover practically all cases of both hot and cold rolling of the softest to the hardest metals under an extremely wide range of work roll sizes, friction conditions, etc. Any such similar attempt in connection with a plot such as Figure 24 represents would result in a welter of overlapping curves and confusion.

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DISCUSSION

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N. H. Polakowski: Dr. Stone undertook a bold and commendable attempt to radically simplify the existing rational (as opposed to purely empirical) methods

of computing rolling pressures and torques in strip production. With this end in view he reduced the geometrically and analytically complicated case of compressing a wide strip between curvilinear rolls to the infinitely simpler case of compression between plane and parallel plates.

It would be too early to try to pass a well-founded judgement on the reliability or otherwise of Dr. Stone's formulas for predicting roll loads involved in cold-reduction of *thin strip*. Very few actual measurements of this sort were published and there is very little material against which the present expressions could be critically checked. However, it is felt that the following observations are in order.

1. By considering the effective thickness of the strip in the roll bite as equal to the mean arithmetic between the entry and exit thicknesses, the author presumably obtains too high a figure compared with reality. Consequently, published values of the coefficient of friction obtained by working back from experimental roll force measurements by using different formulas cannot conceivably be used in Dr. Stone's calculations without some alteration. Has he given some thought to the differences that may be involved?

2. Since the yield strength of a work-hardening metal varies along the contact arc, the manner in which the average is determined must affect the estimated roll force. It appears, however, that the approximation recommended is not unreasonable and the errors it involves may not be serious.

3. It is not at all certain whether the coefficient of friction between roll and strip is really a function of the linear strip speed. The relative speed of roll and strip may be more important than the absolute value of the delivery rate. As an extreme example, one can compare a final 30 to 35 per cent pass on tinplate rolled on a 4000-fpm tandem mill with a normal 0.75 to 2 per cent skin pass on a 5000-fpm temper mill. The relative speed will be about 1300 fpm in the first case but only 40 to 100 fpm in the second.

4. Errors in estimating the coefficient of friction will have a serious effect on the calculated maximum pass pressure and minimum thickness that can be rolled on a given mill. Large variations in the predicted separating forces could be expected on the same grounds for ratios of work roll diameter to strip thickness are around 1000 or above.

5. It would be of interest to know whether the author tried to compare his results with those obtained from other formulas (including perhaps the device designed by the late Frank P. Dahlstrom) by using identical primary data in each case. At present it is not clear whether the various simplifications undertaken in this paper tend to introduce a cumulative error or whether they are selfcompensating to some extent.

From the viewpoint of a rolling mill designer, a correct estimation of the roll forces is probably more difficult a problem than the prediction of roll torque. The maximum torque usually occurs between the first and third pass and it can be fairly closely assessed from the stress-strain curve of the material to be rolled coupled with knowledge of the diameter of the driven roll and specified draft.

The considerations and data contained in the later part of the paper (Figure 23) and which concern the power consumed on "rolling the rolls" are extremely interesting and thought provoking. In this connection I wonder whether the substantial differences in power consumption with work rolls of widely differing diameters, Figure 19, are not partly due to this phenomenon.

Dr. Stone ascribes the extremely high power absorption indicated in Figure 23 to plastic roll hysteresis and he refers in this connection to the blueing of rolls occasionally observed in heavily loaded high speed mills. I venture to suggest that slight slippage between the work and support rolls caused by repeated accelerations and decelerations due to roll eccentricity might be here a concommittant factor. A few years ago, upon inspecting a large and fast sendzimir mill in Europe, I noticed the blueing of the work rolls and have suggested that it may be removed or alleviated by sandblasting the intermediate support rolls. The suggestion proved to be correct and I thought that any minor slippage that could occur between the rolls was eliminated by the increased friction.

It is of interest to note that the "blueing" had no harmful effect whatsoever upon the life of the work rolls. Moreover, the idling mill was subject to the highest rolling pressure that could be attained and then accelerated to top speed (1500-fpm, 2500-hp mill motor). The power absorbed was very small and the rolls remained "white." This observation would support Dr. Stone's statement that the plastic hysteresis losses are insignificant in mills equipped with small diameter work rolls.

T. Sendzimir: Dr. Stone's paper represents another serious effort at the analysis of cold rolling flat products and the theory of the somewhat puzzling phenomena associated with it. I believe it will be one of the milestones of progress in this respect.

I must say that whenever a new survey of this situation is made, it becomes more clear that a small roll diameter has distinct advantages and this paper has forcibly brought to light several points that were not discussed before.

But when drawing conclusions from his investigation, Dr. Stone does not propose, in designing of mills, to go down to the smallest obtainable roll diameters, but rather proposes to stop half way down and be satisfied with rolls such as 10 in. or 8 in. or in some cases, 6 in. diameter for strips in the 30 to 50 in. width class. He only mentioned one disadvantage of rolls that might be considered as too small in that they would require more frequent grinding. This is partly true because the periphery of a 2-in. roll is 10 times smaller than the periphery of a 20-in diam roll, but a 2-in. roll will not require grinding 10 times more often: first because the roll pressure for the same pass is less, secondly because the rollbite is more narrow, therefore there is not nearly as much work of friction and therefore less abrading done on the surface of the roll; and thirdly, because such small rolls can be made of much higher quality steel and heat treated to obtain properties of considerably higher abrasion resistance. Such steels as contain over 2 per cent of carbon and 12 per cent of chrome can only be produced in relatively small diameters and their abrasion resistance is very much higher than it is for the conventional analysis of cold mill rolls.

There is also another important factor connected with the narrow rollbite and that is that front and back tension and especially the back tension, have a much bigger effect on relieving the roll pressure still further because friction in the rollbite interferes less with the free action of the tension.

But, even those arguments only apply in mills where roll changing is a time-consuming operation. With the sendzimir mill, even on a mill rolling 50-in. wide strip, the total time for changing the rolls is less than a minute and therefore, the whole problem of roll changing practice takes an entirely different aspect. In fact, it is worth often to change a roll just for the last pass on stainless steel, for each coil. A 5-ton coil on a mill may represent the value of, say $5,000, and by spending an extra minute on it, a considerably better surface can be obtained by using a mirror finish roll. The same applies to low carbon and other steels where the quality of surface, whether polished or rough, can be consistently maintained because one does not give the roll-changing operation even a thought, so rapid it is.

But, the situation seems to be turning of late, still more forcibly in favor of small rolls, with a new era dawning, namely with the advent of solid tungsten carbide rolls. It is clear to anybody that carbide with its hundred times better abrasion resistance than steel rolls, is a preferable material for the manufacture of cold rolling rolls. The same situation faced the wire drawing industry some thirty years ago when only such small dies as those used in wire drawing could be produced by the new-born tungsten carbide industry. Heretofore, a chilled cast iron die was not even capable of drawing a 300-lb coil of wire to a uniform gage whereas the tungsten carbide die rolled 40 or 50 tons of that wire before it needed attention. The whole revolution was accomplished inside of three or four years.

With cold rolling, essentially the same factors apply, plus the one added factor of roll flattening, which Dr. Stone has so forcibly brought to light and for such gages where roll flattening becomes critical, a carbide roll with its over two times greater modulus of elasticity as compared with steel, is a perfect life saver.

The only problem was to manufacture such rolls, and that was overcome only gradually, until now, completely acceptable tungsten carbide rolls are made in consistently good quality and at reasonable prices, but even today, when, for instance, typical sendzimir mill rolls, such as 3/4-in. diam by 20-in. long or up to 2 1/4-in. diam by 52-in. long, are being produced and have proved to be extremely economical and practical in use. However, who could think of making a solid tungsten carbide roll 20 in. in diam by 50 in. or more in length, plus the length of the necks and so on, which are not necessary on the sendzimir mill?

R. A. Phillips: Dr. Stone has an approach which is extremely useful to one relatively new in the field of analysis of rolling steel. His comments and his analyses are usually based on quite a thorough physical picture which makes them easy to follow.

The method of calculation which Dr. Stone presents makes possible the prediction of roll separating forces and stand horsepower with relative ease. However, as a theory of thin strip rolling it does not lend itself to the problem of predicting the effect on outgoing gage

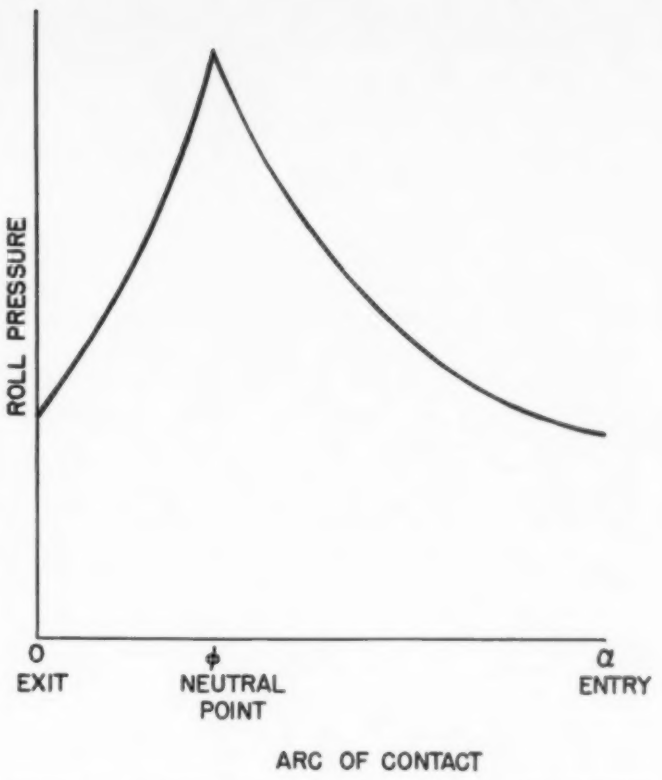

Figure 27 — Sketch shows friction hill diagram for pressure distribution.

of a change in incoming or outgoing tension. This, of course, is important if ones object is to predict the performance of a rolling mill and its associated drive and control equipment.

The assumption is made in the paper that the point of no slip in the roll bite is at the center of the arc of contact. In addition the effective strain yield stress is calculated by subtracting the average of the front and back tension stress from the strain yield stress. The author says that the required specific pressure from the rolls is considerably influenced by the tension effect. Therefore, if front and back tensions do not influence the effective strain yield stress in equal proportions, considerable error may result.

As a test of the consequence of Dr. Stone's assumption that the neutral point is at the center of the arc of contact, assume it is at some other point to see the effect. Figure 27 of this discussion shows a so-called friction hill diagram of pressure distribution. In an article by Hessenberg and Sims[34] an equation (their equation 9) was derived to show the effective yield stress in the roll gap.

$$S_{eff} = S_o - p_1 \left(1 - \frac{\phi_n}{\alpha}\right) - p_2 \frac{\phi_n}{\alpha}$$

where

S_o = strain yield stress

S_{eff} = effective strain yield stress

p_1 = incoming tension

p_2 = outgoing tension

α = angle between exit and entry in roll gap

ϕ_n = angle between exit and neutral point in roll gap

If, as Dr. Stone did, the assumption is made that

$\varphi_n/\alpha = 0.5$ then the above equation reduces to that used by Dr. Stone to calculate effective yield stress. In addition, if p_1 and p_2 are equal as they may be in stands two, three, and four of a five stand tandem mill, S_{eff} is independent of ϕ_n/α. It has been our experience in calculation of pressure distribution in the roll gap with cold reduction that the ratio ϕ_n/α is more usually about 0.3. For this case

$$S_{eff} = S_o - 0.7\ p_1 - 0.3\ p_2$$

Therefore, the assumption which fixes the neutral point at the center of the arc of contact does not result in a theory which correctly predicts the effect of tension on gage; nor can it correctly predict roll separating force except in the special case where incoming and outgoing tensions are equal.

If some way could be found to reduce the frictional energy in the rolling operation, the total power consumed by the operation could be reduced. Dr. Stone shows that a decrease in roll diameter decreases the PMF and thus decreases frictional energy. Another way suggests itself. Consider the case where strip is being rolled with light tensions throughout the mill. If the tensions throughout the mill were held as high as possible, both the effective yield stress and the PMF would be minimized at each stand. This should reduce the total mill horsepower to roll a given schedule.

On this premise, we made some calculations to find out what would happen if we took a rolling schedule where tensions between stands were in the order of 15,000 psi and arbitrarily doubled those tensions calculated while holding the coefficient of friction constant. We found that the total calculated mill horsepower required to reduce the strip decreased by about 15 per cent. This is a conclusion which one could certainly come to by studying this paper because the implication is there.

M. D. Stone: In reply to Mr. Polakowski's comments on the author's theory of thin strip rolling, I should like to state that the basis for simplifying this necessarily complex problem rests on von Karman's[35] and Nadai's[36] basic work, as referred to in Part I[23] of this study. The reliability of the method has been checked for many cases—for example, as shown in Figure 19 of the present paper, in which considerable variation in hp-hr per ton to roll, as a function of work roll diameter, is predicted and checked by many tests on a variety of mills.

Commenting on some of the details referred to by Mr. Polakowski, the author's choice of the use of the arithmetical mean of entry and delivery thickness $t = \frac{t_1 + t_2}{2}$ might be replaced in some cases by the geometric mean $t = \frac{t_1 + 2t_2}{3}$, especially when the strip is extremely thin, but in general this added refinement does not seem justified. It is of course true that the yield stress varies along the arc of contact, but here again it is felt that the elected simplification is justified by overall experimental checks. The matter of variation of rolling friction in the bite as a function of rolling speed is, in the author's opinion, an important development — see Figure 5 of part I of this study [23] referred to earlier. Others, notably Sims and Arthur[24], et al have come to the same conclusion, and demonstrated the effect quite ingeniously. While the relative speed of roll and strip may have a modifying effect, the absolute strip (roll) velocity seems to be the dominating consideration in establishing a sort of pseudo-hydrodynamic condition between roll and strip that causes the equivalent friction to decrease with speed. As more and more attention is given to all these matters, undoubtedly some refinements will be found to be of value.

With regard to a comparison with the late Frank Dahlstrom's calculation board, the author would like to say that the Dahlstrom board is based directly on the author's formulas, and of course, therefore, our results check. The author has one of Dahlstrom's boards, and before the nomographic chart of this paper (Figure 16) was developed, it represented a considerable saving in time (see author's discussion of part I of this study)—but with the use of the nomograph, it is doubtful if the board is worth the expense. As Mr. Polakowski mentions, some of the variations shown in Figure 19 can be ascribed to the hysteresis losses in "rolling the rolls," and it is felt that they account for the discrepancy between tests and calculations for the larger roll diameters, where the effect is of significant magnitude. Mr. Polakowski's observations of "blueing" of rolls in a sendzimir mill due to slippage is of noteworthy interest.

Mr. Sendzimir's comments on the subject paper perhaps quite naturally center around the matter of very small rolls. In discussing this aspect, Mr. Sendzimir states that since the smaller the work roll the less the roll pressure for the same pass, and since the roll bite is narrower, there is less abrading of the roll surface. The author would point out that since all mills are conventionally operated up to the same value of Hertzian contact stress, and since friction forces are independent of area of contact, it is to be expected that a 2-in. diam work roll will have to be changed ten times as often as a 20-in. diam roll. It is not uncommon, as is well known, to change one of the ultra small work rolls three times in the rolling of a single coil—it is true of course that the small rolls require less time per roll change than the larger.

On the matter of roll heating and attendant distortion, giving full credit to a half size work roll requiring as little as 50 per cent in hp-hr per ton rolled—see Figure 19, for stainless steels (which relationship does not continue as still smaller work rolls are used), the volume of the smaller work roll is one fourth of that of the larger, for the same width. Thus the energy per unit volume is twice as much for the smaller roll as for the larger, and hence it necessarily operates at a much higher temperature level, as attested by all operators. Of course, the ultimate in cooling would help in this regard, but particularly for Mr. Sendzimir's mill where a rolling oil is used that is also suitable for bearing lubrication, the cooling ability is inherently less than for coolants used on mills where the coolant and lubricating systems can be kept separate.

Mr. Sendzimir is of course quite correct in stating that small work roll mills require greater precision in manufacture, and also in maintenance repairs. Roughly, a mill having half the work roll diameter of a larger

mill requires half the chock clearances, and the like—and for one-tenth work roll size, the tolerances must be proportionately closer. The use of tungsten carbide rolls, as Mr. Sendzimir states, has certain advantages, particularly as to elastic modulus and wear resistance, that merit its serious consideration—a possibility not available for large rolls because of their tremendous cost and difficulty of manufacture.

Mr. Phillips' comments are with particular reference to the effects of front and back tension on rolling pressures and powers—and especially with regard to the fact that back tension has a greater effect in reducing rolling pressure than front tension. The author recognizes this effect, and in Part I stated in regard to Lueg and Schultze's tests referred to "these tests showed reductions in rolling pressures of up to 35 per cent by heavy back tension, and up to 20 per cent by heavy front tension." The writer has used an average of front and back tension for simplification only, as has also Messrs. Hessenberg and Sims in the paper referred to by Mr. Phillips, recognizing that a slight underestimation in pressure is involved, but stated in their case "the errors involved . . . over a wide range of conditions are not much greater than the variation of ±0.5 tons per inch of width." If one examines Lueg's data closely, the ratio of effectiveness in reducing rolling pressure, of back tension to front tension is 54 to 46 per cent for a 20 per cent cold reduction pass, 65 to 35 per cent for a 30 per cent pass, and 74 to 26 per cent for a 40 per cent pass—so that a 60 to 40 per cent ratio might be taken as more correct for the schedule calculated in Figure 17, for instance. But even using Mr. Phillips' suggested 70 to 30 per cent ratio (which is too high), the maximum error in pressure, occurring at the low end, is only 2½ per cent. However, for the objective Mr. Phillips has in mind—namely, for predicting gage, in a tandem mill, for instance—the writer will agree that a 60 to 40 per cent division is more correct to take, and perhaps without a real complication in calculation procedure. In passing, with regard to Mr. Phillips' assumption that the location of the neutral plane (no-slip point) is usually 0.30 of the contact arc, it should be pointed out that even when no tensions are used, this factor varies from 0.50 down to 0.25 depending on bite angle, friction values, etc. And when tensions are involved, the factor may vary all the way from 1.00 (for high front tensions) down to 0 (for high back tensions)—see, for instance, Nadai's work[36], cited earlier.

Mr. Phillips' statements regarding the effect of tension in reducing mill power are certainly true, as we have always appreciated.

T. Sendzimir: Dr. Stone has now explained that there is another factor militating against the use of small rolls, besides the more frequent grinding, namely, it is more difficult to produce a flat strip on the mill. Dr. Stone attributes this to a smaller heat absorbing capacity of a smaller weight roll, and therefore, a heat distortion so that a mill shows symptoms of being capricious.

With our experience in rolling medium and light gage steel on extremely small rolls, extending over 20 years, we know this behavior quite well and would say that a part of it only can be attributed to heat. Our older mills have been also suffering from it and we have remedied it by our improved internal spray and cooling procedure with strategically placed sprays and a controlled rate of cooling across the width of the strip.

But, we found that the solution of the problem depends upon an extreme precision of the rolls themselves and their backing elements. Small rolls are naturally more keen in penetrating the metal, therefore, the slightest differences in roll pressure, such as those caused by inaccuracies in the rolls themselves, in their supporting elements, and in the mill housing will inevitably translate themselves into a wavy condition of the strip. Here, of course, the sendzimir mill with its rigid housing and extreme precision of backing, has a marked superiority over mills with roll backing where the body of the backing roll itself, by its own resistance to bending, is supporting the more slender work roll.

With the considerably lessened role that friction is playing when using such extremely small rolls, it is possible even to iron out inaccuracies originally present in the hot rolled strip on this almost absolutely rigid mill. Such strip is easily side-spreading slightly in the rollbite so that the final gage after cold rolling is more accurate percentually than was the heavy hot rolled strip.

The use of tungsten carbide rolls makes the problem of producing a flat strip while using ultra-small rolls, still more simple because its coefficient of thermal dilation is much smaller in comparison to steel, so that there is less heat distortion to control.

J. D. Keller: (By mail) Concerning the matters discussed in the first part of Dr. Stone's present paper, there would seem to be two distinct questions involved:

1. Does the coefficient of friction of the strip on the rolls decrease continuously as the speed of rolling increases?

2. Is this change of friction, if it occurs, responsible for all or most of the decrease of strip thickness which is observed to occur as the rolling speed is increased (when other factors are held constant)?

The agreement of Stone's friction values with those of Sims and Arthur, which is close enough for practical purposes, would seem to answer the first question in the affirmative beyond reasonable doubt, if it were not that both sets of results were derived not by direct measurement but inferentially, as Stone very properly points out, on the basis of the friction-hill theory of rolling. Incidentally, this is the same general method used by the writer in 1942[9].

Since the theories used by both Stone and Sims are imperfect in that they neglect the Korber "Haftgebiet" or region of adhesion with no slip, conclusions drawn from results obtained by this method must still be considered questionable. And the fact that the results of other methods for determining the friction coefficient which do not depend on rolling theory, namely those of Whitton and Ford cited by Stone,[25] show so little variation of the coefficient as to be scarcely beyond the range of experimental error, would seem to cast further doubt on the reliability of the inferential method.

In view of all this, the writer would answer the first

question, at present, as "very probable, but not yet definitely proved."

Incidentally, a continuous decrease of the friction coefficient with increase of speed would not necessarily prove, as Dr. Stone seems to think, that hydrodynamic lubrication conditions exist in the contact area or "bite," for it is known that, for example, in sliding bearings where hydrodynamic conditions exist, as the speed is increased, the friction coefficient first drops to a minimum value at a quite low speed and then rises steadily with further increase of speed.

A more cogent argument for the presence of hydrodynamic lubrication is furnished by the low values obtained for μ, namely 0.03 to 0.04, as compared with the usual 0.085 to 0.11 for boundary lubrication; although values nearly as low (0.042) can exist in boundary lubrication under some conditions, as shown by Claypoole.

In the writer's view, the *overall* coefficient of friction in the "bite" is in reality nothing more than a statistical average of a multitude of different values existing in small localized areas. The greatest values of μ exist at the high spots of the roll and strip surfaces where actual metallic contact occurs, with alternate welding-together and tearing-apart of minute areas as shown by Bowden and confirmed by Nekervis and Evans.[15] Intermediate values of μ occur between other parts of the adjacent surfaces which are nearly parallel and in close proximity; here boundary lubrication exists. The lowest values of μ exist along the sloping flanks of such areas, which slopes may in effect act as minute oil wedges and may produce something like hydrodynamic conditions; these latter areas, however, usually carry only a minor fraction of the total load, the greater part being taken by the areas having boundary lubrication.

According to this view, a smooth decrease of the overall μ with increase of speed would result from the sloped areas taking a greater and greater fraction of the load, wedging the surfaces slightly further apart, reducing the number of points or the total area of solid contact, and permitting the number of layers of oil molecules in the boundary-lubrication areas to increase, with corresponding reduction of μ in these areas. In other words, the areas of high friction would be continuously decreased and those of low friction continuously increased, with increase of speed. A more complete discussion was given in STEEL, March 19, 1951, pp. 80-86 and March 26, pp. 84-89.

As to the second question, both Stone and Sims are convinced that variation of the friction coefficient adequately accounts for the whole of the observed variation of strip thickness with rolling speed. The work of Billigmann and Pomp (Stahl & Eisen, v. 74, Aug. 8, 1954, pp. 441-461) in an indirect way lends some support to this view, for although they did not try to determine the friction coefficient, they did measure the variation of roll force with speed for both lubricated and dry rolls, up to about 1200 fpm, and found that with lubrication, as the speed was increased the force decreased continuously . . . as much as 50 per cent for very thin material . . . but when rolling dry, at speeds above 150 fpm the force *increased* on the average about 20 per cent to 1200 fpm.

However, in view of the numerous other factors cited in a former publication (STEEL, July 23, 1951, pp. 84-87 and, August 13, 1951, pp. 88-91), while agreeing that variation of the friction coefficient probably plays the predominant part, the writer is not fully convinced that it furnishes the whole explanation. In particular, it is thought that the hysteresis effect which was discussed in those articles and is now again brought into prominence by Dr. Stone in another connection, cannot yet be ruled out as a possible partial explanation of the variation of strip thickness with speed.

I am glad to see that Dr. Stone now recognizes the fact that there is a limiting thickness (or thinness) in rolling, as this checks the work done by the present discusser and reprinted in an article entitled "How Thin Can Strip Be Rolled?",[22] which contained a brief but adequate mathematical treatment of the matter.

Dr. Stone's alinement chart, Figure 16, is an interesting development and should be of value. It brings to mind an ingenious device invented by the late Frank Dahlstrom, which included several scales ruled on celluloid or lucite and arranged to be shifted to and clamped in any desired position. This device also took care of the effect of roll flattening as well as roll radius, friction coefficient and compressive resistance of the strip material. With it, almost any problem of forces in strip rolling could be quickly solved. However, Dahlstrom's device and Stone's nomographic chart are both based on a somewhat incomplete theory of rolling, as mentioned previously.

One highly commendable feature of Dr. Stone's present paper is the comparison of calculated results with actually measured values of power consumption, and publication of the latter.

By far the most important feature, however, in the writer's opinion, is the calling of attention to the actions occurring at the contact of the work roll with the back-up roll, and the power loss and heat development resulting therefrom. Dr. Stone seems to attribute this entirely to plastic hysteresis of the roll material under stresses either reversed, or alternately applied and removed. That such action is to be expected will be evident from Figures 28 and 29 of this discussion, which embody the results of tests made in April 1952, at the writer's instigation, by students of I. E. Madsen at Carnegie Institute of Technology on specimens cut from the outer two in. of a heat treated, cast alloy steel roll of 56-in. diameter, intended for a hot strip mill but of a type also used for cold strip mills.

The purpose of the tests was to determine whether the Bauschinger effect or plastic hysteresis really occurs in this very hard roll material. The loop curve obtained in reverse torsion amply demonstrates that it does occur.

That plastic flow occurs in the rolls even under ordinary working pressures, is shown by the observed fact that if strip mill rolls when not turning are allowed to remain under load for any appreciable time, a narrow longitudinal flat spot or streak, corresponding to the surface of contact of the work roll with the back-up roll, develops in their surfaces and remains permanently.

The question that has long puzzled the writer in this

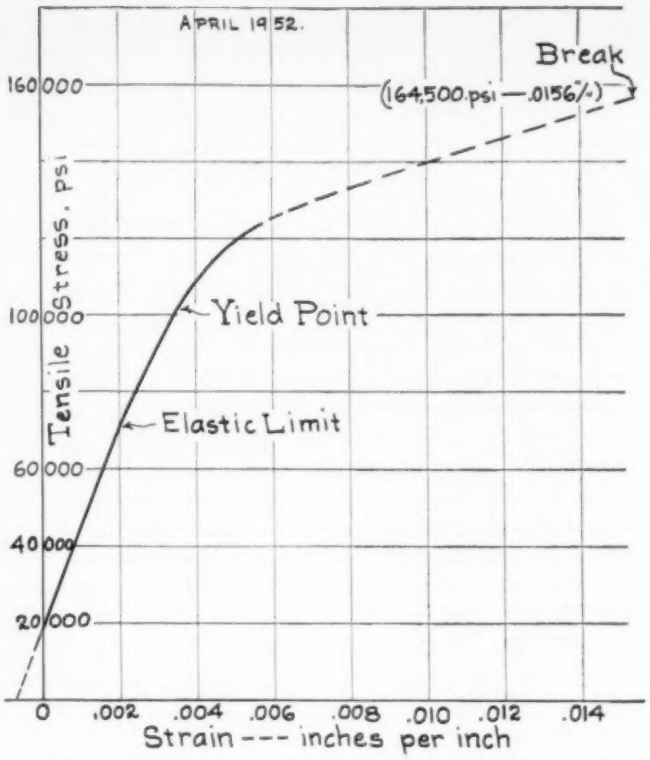

Figure 28 — Stress-strain curve is made on specimen from outer 2 in. of a 56-in. diam cast alloy, heat-treated roll with Rockwell C hardness of 39.

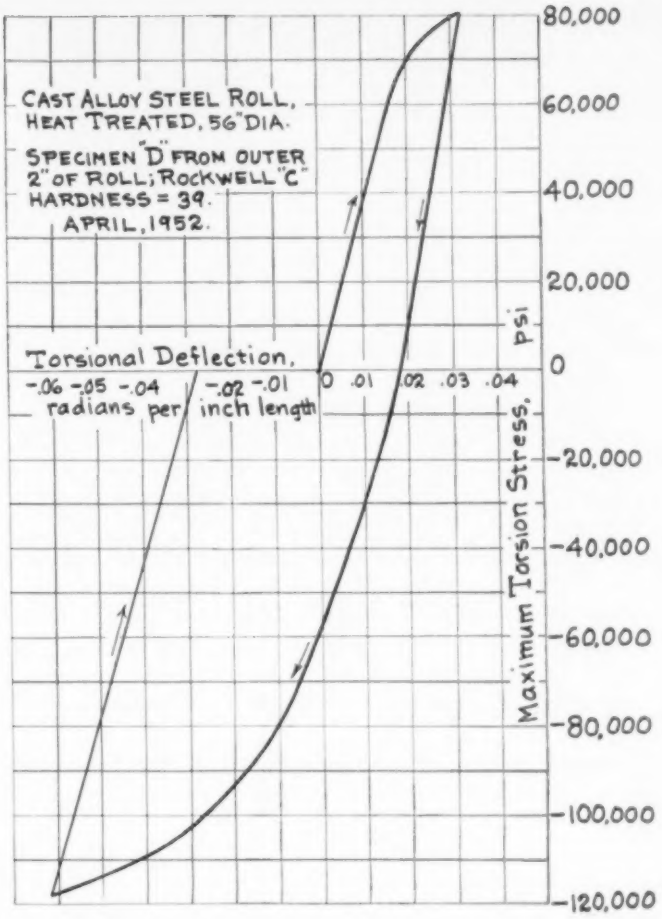

Figure 29 — Under torsional load, there is a very definite Bauschinger effect in this material from a cast alloy roll.

connection is, if such repeated plastic flow occurs, how can the roll material hold together; why does it not quickly disintegrate? However, S. Timoshenko on the basis of tests by Hopkinson and Williams concluded that it is possible to have hysteresis loops (with corresponding heat development) which will never cause destruction, and that this can be considered as the true "elastic hysteresis." It probably has something to do with the fact that in no material is there perfect elasticity, and with the existance of the tessellated or textural internal stresses.

However, in the writer's view, hysteresis is only one of three factors which cause power loss and heat development at the contact of work rolls with back-up rolls. The first factor, namely hysteresis, develops heat within the roll, though probably not far inside the surface, whereas the other two develop heat directly at the surface.

The second factor is tangential friction. As shown by Osborne Reynolds, and by H. Fromm, and by A. Palmgren (the latter in "Ball and Roller Bearing Engineering," SKF Industries, Phila., 1946), except when the contacting rolls have the same diameter, slip occurs in the outer parts of their contact length, even if there is no tangential traction. At the middle of the contact length a region of adhesion or no-slip exists (just as in the "bite" of the work rolls), but on either side of this is a region where the contacting surfaces slide on each other . . . in one direction on the "on" side, in the opposite direction at the "off" side of the contact length. And if one roll drives the other, producing tangential traction, the energy loss due to tangential slip is much increased.

Fromm's comparison of his calculated results, assuming perfect elasticity, with test results of Jahn for a steel roller contacting a steel rail, and those of Sachs for wrought iron discs in contact, showed the actual slip to be more than three times the calculated slip. The energy loss from this source, therefore, cannot be neglected.

The third factor causing loss of energy at the contact of work roll with back-up roll, is endwise slip caused by "crossing" of the rolls. By the latter is meant a slight misalinement of the axes. The result of this is, after a number of revolutions, to force the back-up roll against its thrust bearing at one side of the mill, and the work roll against its thrust bearing at the other side. So great is the endwise thrust that visitors to strip mills are warned not to stand opposite the ends of the rolls, for breakage of the longitudinal bolts holding the bearing caps might occur at any time, and then the heads of the breaking bolts are thrown out like bullets.

Theoretically, for rigid rolls, so far as the endwise force is concerned the magnitude of the angle between the axes of the crossed rolls makes no difference; a thousandth of a degree is as bad as a whole degree in mills where the roll pressure is kept on without remission for a large number of revolutions. Actually, however, it seems as if a sort of axial elastic creep occurs between the contacting roll surfaces, which relieves the end thrust to a considerable extent if the angle of crossing is very small.

As for the energy loss, while the force required to

slide the rolls endwise on each other is tremendous, the energy lost in doing this decreases about in direct proportion as the angle of crossing is reduced. In present practice, especial care is taken to maintain the roll alinement as nearly correct as possible. But in spite of the greatest care, it can never be perfect, and in the writer's judgment the heat developed by the unavoidable endwise slip is at least equally as important as the hysteresis loss or the tangential slip.

This opinion is based on experiments with needle bearings, made some years ago by Professor Trinks and the writer at Carnegie Institute of Technology. Except when the lubrication was especially copious, it was found that even under rather light loads, even a slight "crossing" or misalinement of the needle rollers, intentionally produced, caused excessive friction, and in some cases caused binding to such an extent that the journal could not be turned at all.

M. D. Stone: Mr. Keller's comments on the author's contention that roll bite friction, or at least equivalent bite friction, decreases with rolling speed really refers to Part I of this study—but it is still the writer's feeling, since substantiated by Sims[24], and others that it is the best explanation of what is taking place. Mr. Keller's discussion on the existence of a limiting rolling thickness (thinness) also refers to the author's earlier paper (see text following equation (12) in Part I of this paper). Mr. Keller's reference to Dahlstrom's calculating board is along the lines of Mr. Polakowski's discussion, and accordingly our earlier comments would apply again.

Mr. Keller mentions that, in his opinion, there are two additional sources of power loss at the point of contact of two rolls to that of contact hysteresis—namely, tangential friction within the contact area and roll crossing. The author has considered the first effect (even for unequal roll diameters), with due regard for O. Reynold's work along these lines, but must agree with Tabor[32][33] that it is generally negligible in magnitude compared to contact hysteresis losses. With regard to the possibility of roll crossing loss effects, it would be the writer's feeling that this is very small as well, since axial thrust loads due to crossing are usually less than one per cent of the rolling pressure (attested by the fact that the thrust capacity of the usual work roll bearing is less than one per cent of the rated capacity of back-up roll bearings)—and the associated power losses would be even less.

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Application of Oil Mist Lubrication in the steel industry

By T. M. MURPHY
Manager Industrial Sales, Alemite Division
Stewart-Warner Corp., Chicago, Ill.

. . . . application of lubricant by means of an oil mist has a number of advantages . . . . for successful application, however, it is necessary that the oil be kept clean and air lines supplying lubricated bearings must be clean and free of moisture . . . . lubricant requirements of the bearings must also be within capacity of number of oil mist units applied . . . .

▲ THE past five years have seen many successful applications of the oil mist method of lubrication. However, numerous inquiries and reports from the field, on its ever-widening application, indicate that a review of the oil mist principle of lubrication is in order.

Oil mist lubrication may be defined as a method of converting liquid oil into an airborne mist state that may be conveyed in an air stream through a system of piping to a number of bearings for the purpose of lubrication.

The objectives of lubrication being sought after, that led to the development of the oil mist principle, were the desire to have continuous controlled lubrication for high rotational speed anti-friction type bearings, and to provide an effective protection for these bearings against the penetration of the impurities that abound in the atmosphere of most shops and plants. It is a recognized fact that the increased speeds demanded of bearings today present problems of lubrication and dissipation of frictional heat. It is also a recognized fact that the penetration into the bearing of abrasive material, from the atmosphere, takes as great a toll from the life of a bearing as any other factor.

The first applications of an oil mist principle of lubrication were utilized when an air line oiler was applied to the air lines supplying pneumatic tools. However, the oil mist generated by an air line oiler varied uncontrollably in oil mist particle size. In fact, 94 to 96 per cent of the mist generated was of so large a particle size that it readily collected on the walls of the conveying pipe or tubing. This fact prevented equitable or controlled distribution of the oil to more than one point of application.

Present day oil mist lubricator design has eliminated this problem and now about 96 per cent of the mist generated is of a particle size two to five microns in diameter that can be distributed and controlled.

The primary components of the oil mist lubricator are:

1. Oil reservoir.
2. Air supply inlet.
3. Atomizing nozzle.
4. Baffle plate.
5. Oil mist outlet.

Let us now look at the "oil mist" lubricator unit (Figure 1) and examine its operation. This line drawing of the typical "oil mist" lubricator has been numbered to help follow the description.

Oil is poured through inlet No. 1 into the reservoir No. 2. A filtered, water-free air supply line is connected to point No. 3 or No. 4, whichever is more convenient. Air flows through the air regulator No. 5 where it is reduced to the desired operating pressure, which is recorded on the air gage No. 6. Regulated air pressure now flows through the passage No. 7, through the lubricator and out the outlet No. 8. We then open the oil flow valve No. 9. When this is done, oil passes through a strainer No. 10 and up suction tube No. 11. The oil which is drawn up suction tube No. 11 is mixed with the air and atomized in the modified venturi passage No. 7. This mixture of oil and air blasts against a baffle plate No. 12, which collects the large droplets of oil and returns them to the oil reservoir No. 2, leaving only an atmosphere filled with microscopic oil mist particles of approximately two to five microns in size. Thus, only the very smallest drops of oil pass through the outlet No. 8. The mixture of the microscopic oil drops and air is white, like a mist.

The amount of air passing through the oil mist lubricator at 20 psi is approximately 1.2 cfm. The amount of an average 500 ssu viscosity at 100 F mineral oil at 75 F being dispersed into the air is 0.010 cu in., or approximately two drops of oil per cu ft of air. The mixture, therefore, is not sufficiently concentrated to become inflammable.

The oil mist can be conveyed through ½ in., or larger, pipes for recommended distances of 30 ft in any direction from the lubricator without being affected to any marked extent. In tests it has been successfully passed through as much as 100-ft of tubing. However, if the oil mist is passed through small bores, even for short distances, the amount of precipitation or condensation will be considerable.

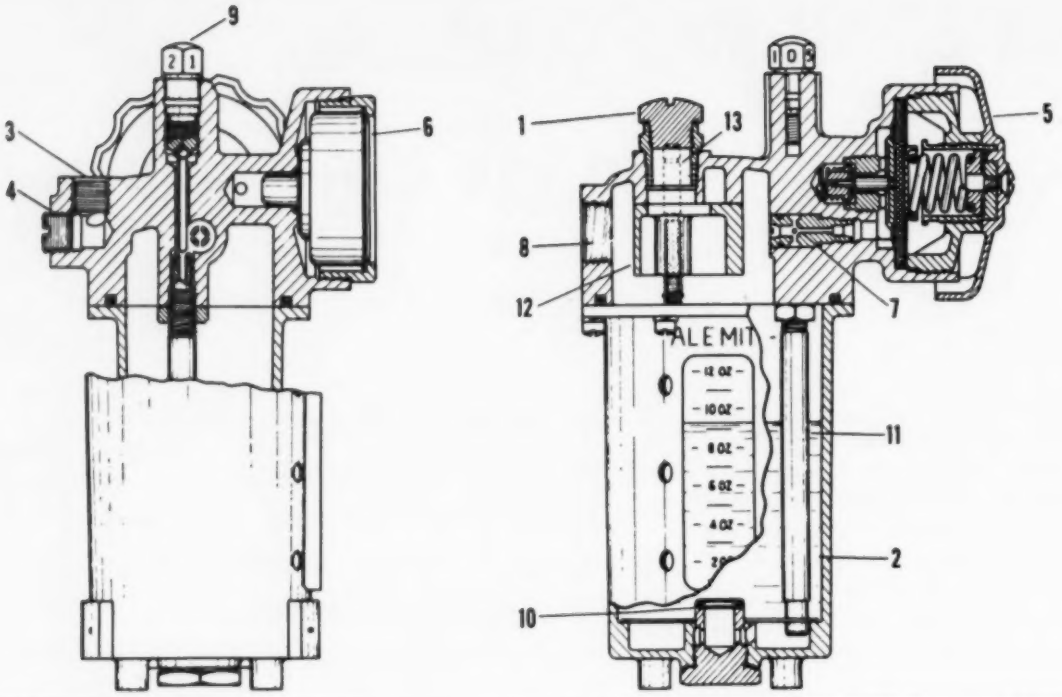


Figure 1 — The primary components of the oil mist lubricator are given by this schematic drawing.

The fact that oil can be converted to mist and conveyed reasonable distances through pipes of suitable size, without any marked precipitation effect, and then can be reconverted to liquid oil at will by passing for short distances, through small bore holes, gives considerable control over its application for the solution of lubrication problems.

Thus, the oil mist can be applied in three ways: namely, as straight mist as generated, as a semi-condensed mist by passing it through spray fittings of a reduced bore, or by passing it through fittings of very small bore that condenses approximately 90 per cent of the mist back to liquid oil droplets. See Figure 2.

As stated earlier, it was the search for a good method for the lubrication of anti-friction bearings that led to the development of the oil mist principle.

The oil mist method has proved to be a good method of lubrication between the balls or rollers and their retainers, cages and races.

It does assist in dissipating frictional heat.

The internal pressure of the oil mist air in the bearing does assist in sealing the bearing housing against the entry of dirt and other abrasive materials.

Fresh, cool lubricating oil can be applied in small quantities continuously.

The oil mist lubrication method, because of its oil consumption economy and its merit as an aid to good housekeeping, has been successfully applied to many plain bearings, gear trains, chains, etc. However, frictional-type bearing surfaces must have full film lubrication and the engineer must see to it that such a film can be developed and maintained for each application.

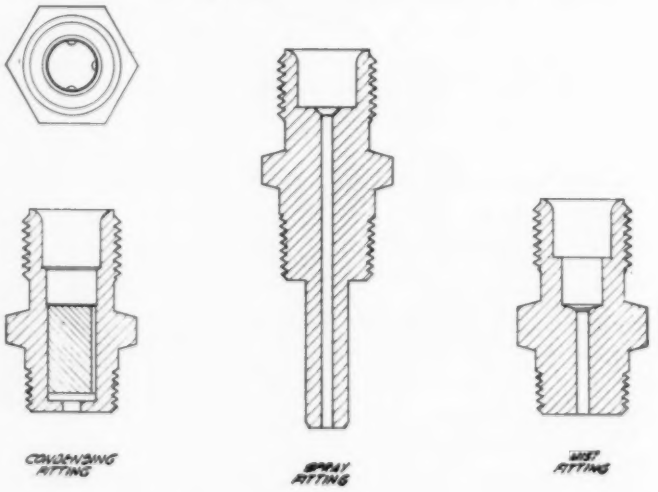
To date oil mist lubrication has done a very creditable job in general industry. In order to be specific about the iron and steel industry, a report on some of its applications on steel mill equipment will be given.

The application of oil through the oil mist method has successfully replaced grease lubrication on both single stand and 4-high stands in a number of steel mills (Figure 3). Oil mist is applied through the normal grease inlet ports of the anti-friction bearings after the grease lubricant had been removed from these bearings. Examination of the bearings after a full year's operation has proved that the lubrication method is very satisfactory.

The fact that this lubrication method is satisfactory is very important in those mills wherein they are using roll oil for the rolling of the steel, because of other factors in addition to lubrication itself. The cost of lubrication has been reduced from approximately $4.00 per day to approximately 3¢ to 4¢ per day.

With the grease lubrication method, the rolling oils frequently become contaminated with the excess grease lubricant that would leak from the bearings. Since the application of oil mist, this contamination of rolling oils has been practically eliminated. For example, when the work roll and back-up roll bearings were lubricated with grease lubricant, the rolling oil solution had to be replaced on an average of 18 to 19 times over a six-months' period. After the application

Figure 2 — Three types of nozzles are used for the three methods of applying oil mist.



of oil mist, the rolling oil changes were reduced to approximately nine or ten changes over a comparable period. This represents a saving of approximately $480.00 a month for roll oil solution. In addition to the above saving, the lubrication time has been immediately reduced, and the operating bearing temperature of the bearing has been reduced.

The application of the oil mist system has been very successful on steel mill tinning lines (Figure 4).

Again the oil mist principle has been found to provide adequate lubrication for the bearings at a minimum cost from both the lubricant consumption point of view and from the application point of view, but the outstanding savings are in the prevention of the contamination of the tinning solution, in the prevention of staining the steel and in good housekeeping.

In addition to the foregoing savings, it may also be pointed out that the oil mist method of lubrication reduced the frictional drag on the rollers, particularly idler rolls. On one particular set-up, the idler rolls were normally driven by the strip, however, the grease lubrication auxiliary drives had to be applied to these rolls to start them in motion and this resulted in scratches on the tin plate, causing scrap. After the oil mist method was applied, the friction in the idler roll bearings was reduced to the point that the rolls moved freely with the strip and it was not even necessary to operate the auxiliary drives.

The oil mist method of lubrication has also increased the life of the anti-friction bearings on the tinning lines by preventing the seepage of acid fumes into the bearings. It is possible to prevent this contamination because with the oil mist method, the pressure within the bearings is maintained at a ratio higher than the atmospheric pressure outside the bearings and by the fact that clean air and oil is passing into the bearings when the air escapes through the seals.

Oil mist has also been successfully applied to furnace fan bearings. It has been reported that a number of fans operating in very high temperatures required bearing replacements of three or four bearings per month. Since the application of oil mist, conveyed through stainless steel tubing and fittings, it is now a rare case to change a fan bearing.

These are only a few examples of the successful application of oil mist in the steel industry. It has been similarly successful in the aluminum industry and in the chemical industry.

Naturally, the oil mist system can be applied to machines with various control accessories. For instance, heaters are available for the oil mist units to keep the oil at a constant temperature and constant viscosity, entirely independent of all ambient temperatures surrounding the oil mist units. Low level devices may be applied to the oil mist units to give the operator sufficient warning when the level of the oil in the oil mist unit reaches a critical level. Gages and signal devices may be applied both to the air line supplying the oil mist unit to indicate any air failure and also to the mist line to indicate any failure in the mist line pressure.

There are only a few basic fundamentals that must be adhered to for the successful application of the oil mist method of lubrication. The oil put into the oil mist units must be kept clean. The air lines supplying the mist lubricator and bearings must also be kept clean and free of moisture. The engineer must be careful to see that the lubrication requirements of the bearings to be lubricated are within the capacity of the number of oil mist units applied.

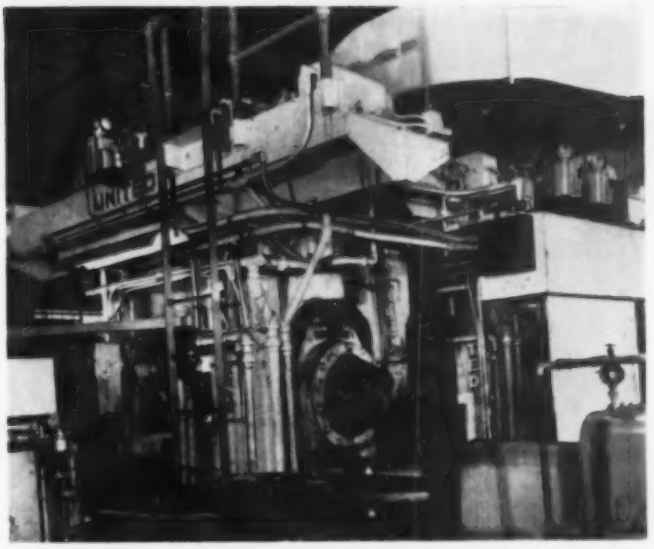


Figure 3—Oil mist lubrication has been applied to back-up and work roll bearings in sizes up to 37 in. inside diam.

In conclusion, may we say that the oil mist principle of lubrication has given us results considerably in excess of what was hoped for when it was originally developed.

DISCUSSION

PRESENTED BY

G. M. KYLE, Assistant Mechanical Superintendent, Inland Steel Co., East Chicago, Ind.

KARL A. ARNOLD, Lubrication Engineer, National Tube Division, United States Steel Corp., Ellwood City, Pa.

FRANK GRAY, Lubrication Engineer, United States Steel Corp., Gary Steel Works, Gary, Ind.

JOHN J. SEATON, Lubrication Technician, Lubricants Testing Laboratory, National Tube Division, United States Steel Corp., Pittsburgh, Pa.

T. M. MURPHY, Manager Industrial Sales, Alemite Division, Stewart-Warner Corp., Chicago, Ill.

G. M. Kyle: At Inland we have used the oil mist principle on two types of applications. On our electrolytic tinning line we have lubricated some self-alining anti-friction bearings above the final rinse tank between the plating tank and the fusion furnace. We changed from the grease system to the mist method in order to eliminate excess grease from adhering to the strip and damaging the product. The oil mist application improved bearing life, reduced lubricating costs, provided a cleaner strip and required about the same amount of maintenance as conventional grease systems.

Another application on which we have used the oil mist principle is on the spray lubrication of billet

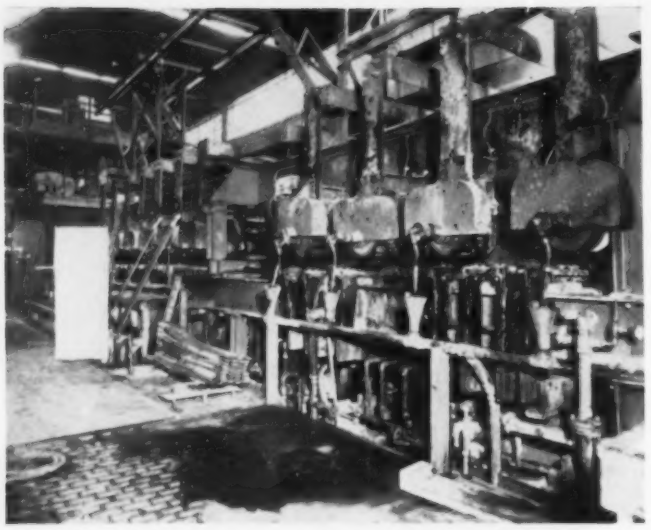


Figure 4 — Oil mist works well on tinning lines and one outstanding advantage is the prevention of contamination of the tinning solution.

transfer chains and pickle line scrap conveyor chains. On both of these applications, the chains were adequately lubricated with a minimum of excess oil leading to general cleanliness and good housekeeping.

I would be interested in learning how large an anti-friction bearing on back-up or work rolls has been successfully lubricated by the oil mist method, on what kind of a mill, and at what rolling speed.

Karl A. Arnold: Mr. Murphy has given a very good insight into the uses and capabilities of oil mist lubrication. Air mist lubrication offers an outstanding feature, especially with anti-friction bearings, of controlling the oil supply and at the same time providing cooling air to the bearing. We have all seen well oiled ball bearings which ran fairly warm. This heat expands the close fitted bearing parts and in case a little more heat is generated, the bearing is subject to seizure. The air mist system provides sufficient cooling air to keep a bearing from excessive normal heat, consequently should additional heat be generated, the bearing does not become hot enough to seize.

The oil mist systems are readily adaptable to high speed bearings which are difficult to keep operating by conventional lubricating practices. Many of these bearings are found in machine tools and other high speed equipment.

Like any other lubricating system, it must be used in applications conducive to its good operation for it is not a cure-all for many installations.

I would like to ask Mr. Murphy a question, "What has been your experience with oil mist lubrication relating to maintenance of clean dry air?"

Frank Gray: This method of oil conservation is not dissimilar to the method of compressor and steam cylinder lubrication where oil application is measured in drops, and oil usage is maintained at a minimum as an operational requirement.

The examples of oil mist applications in the steel industry emphasize the fact that most of the grease and oil used by the ordinary practices are in excess of the actual bearing requirement. The practice of flushing the bearing with the lubricant to eliminate abrasive contamination requires less attention and is a guarantee of an adequate oil film. However, it is a waste of lubricant and often results in poor housekeeping.

John J. Seaton: The United States Steel Corp. is always interested in finding proper, suitable, and economical uses at its plants for improved processes and equipment. The U. S. Steel lubricant testing laboratory in Pittsburgh has been the central location for investigation and testing of the oil mist to find the correct application for its use in the plants. Realizing the various possibilities of the oil mist, a unit owned by the laboratory has been placed at the disposal of all lubrication engineers in the plants along with a trained technician from the laboratory to explain its uses and limitations and help, if possible, in test installations.

An interesting test program was carried on at Christy Park Works, National Tube Division, U. S. Steel Corp., in McKeesport, Pa. The use of the oil mist as a carrier for soluble cutting oils proved satisfactory on certain applications. One test was conducted on a 25-in. contour lathe using carbide tip steel tools. The purpose of the test was to compare the oil mist with conventional circulating flood type applications.

The settings on the oil mist apparatus were as follows: air pressure 30 psi, number 2 setting on the oil flow regulator, and 9 turns inward on the particle size valve located on top of the machine just a little to one side of the oil flow regulator.

The machinist was instructed to run his machine under normal operation with the exception that he would periodically transfer from one type application to the other. Complete records were taken on the rpm of the lathe, the size cut, the type applicator, tool life and material used. At the completion of the above test it was generally agreed that the oil mist was fully comparable to the conventional application as far as smoothness of the piece and finished work were concerned. The lubricant consumed was 16 oz in 8 hours of continuous operation, which is a reduction of 65 per cent by the oil mist application. The performance was much superior as to cleanliness, elimination of stagnant odor, and ease of handling. A much cooler tool, apparantly caused by the force of air, resulted in longer tool life.

Note also was made of the color and condition of the chips as this was of prime importance to the safety of the operator. The use of the oil mist kept the chips brown and caused the chip to snap of its own accord and drop to the trough below, whereas with the conventional type application, the chips were blue and had to be snapped off regularly by the lathe operator.

Another test was conducted on a large pipe cut-off machine. This is a two-tool machine used for the purpose of cutting large diameter pipe into short sections. The design of the machine utilizes one tool on each side of the rotating pipe, in which the second tool must be inverted. The position of the cutting tools demand the oil mist unit be placed at too great a distance from the point of application. The distance that had to be covered, plus the necessary use of two orifices, resulted in too light an application for the severe conditions that are imposed by the operation. However, under these severe conditions, the tool life on the machine was not increased or decreased over a 24-hour period. The in-

verted tool had a definite disadvantage due to the constant damaging of the spray nozzles by unwieldy chips. With the use of two oil mist units, and adequate chip breakers in front of the nozzles, application of the oil mist may be practical, but as the test was run the application is not justified.

These tests are strictly experimental and would require additional experience before placing in production. However, we hope to increase our knowledge by exploring the range of oil mist applications.

T. M. Murphy: I am not acquainted with the properties of phosphate esters and their possible use in an oil mist unit. However, I can say that almost any liquid with a viscosity not exceeding 500 to 600 saybolt seconds and not more volatile than kerosene or very light lubricating oil can be misted in an oil mist unit. We have tried to mist plain water, but without success. Some satisfactory misting has been accomplished with soluble oil in water.

A number of plants have done considerable work in machine tool cutting and grinding with the oil mist principle. However, it is our opinion that a great deal more work in both design and application needs to be done in order to improve this possibility. One aircraft engine manufacturer has told of an incident wherein they started machine cutting with the oil mist principle. They had a number of aircraft sub-assemblies ready to ship out when they discovered that one small cutting operation had not been performed. Ordinarily to prevent contamination by cutting fluid, the sub-assemblies would have had to be completely disassembled before correction could be accomplished.

Considerable time and expense would have been lost. It was decided to try to do the cutting operation using the oil mist principle and without disassembling the aircraft units. The job was successful and this led to numerous other oil mist applications for cutting.

Originally, the oil mist principle of lubrication on diamond grinding wheels was recommended with the purpose in mind of reducing the diamond wheel wear. However, in addition to increasing the life of the diamond wheels, it was discovered that the oil mist cooling method reduced by twenty-five per cent the tendency of the carbide tipped tool to fracture when being ground.

With regard to the question about clean, dry air for operation of the oil mist lubricator, we must say that this is a necessity. Present commercial oil mist units are equipped with a water separator that will remove approximately ninty-five per cent of the removable moisture from average factory air. However, air lines that are subjected to excessive water, scale, blow-by oil, carbon, etc., must be equipped with auxiliary filters and water separators.

Oil mist lubrication has been successfully applied to the back-up and work roll bearings. Some of the largest bearings that it has been applied to are 34-in. and 37-in. inside diam four-row roller bearings. We do not have an accurate figure on the speed and loads on these bearings.

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Distribution of Power in a Modern Cold Mill

By E. A. YOUNG
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Allis-Chalmers Manufacturing Co.
Milwaukee, Wis.

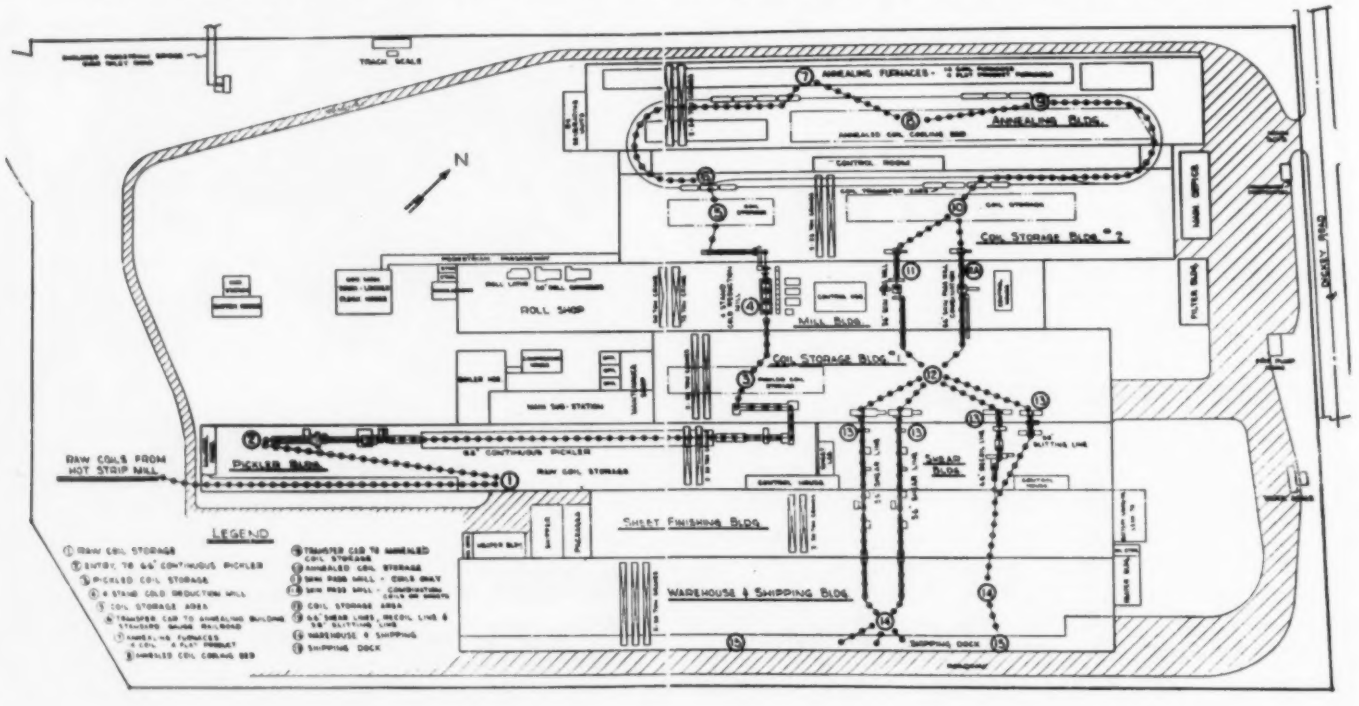
New power distribution system at Youngstown's Indiana Harbor works was made an underground system .... pump type rectifiers were selected over vacuum sealed rectifiers .... distribution voltages are 11,000, 2300, and 440.

▲ THE cold reduced sheet mill at Indiana Harbor was built in 1953. It was designed to produce finished cold reduced sheet products at the rate of 40,000 tons per month. Primary products shipped from this mill are used mostly for automobile bodies, refrigerators, stoves and similar applications.

It was estimated that the power requirements for full output would be approximately 20,000 kw. Since that amount of power was not available from the plant system, the new mill is fed exclusively from a public utility company.

The mill was laid out to have a minimum amount of handling of material in process (Figure 1). The coils are brought into the pickler building by car or truck, and stored along side the line by crane. Coils are put on the entry conveyor by crane and taken off the delivery end of the line by conveyor. The delivery conveyor of the pickler transfers the pickled coils into No. 1 coil storage, where they are stored by crane. Coils are taken out of storage, and deposited on the entry conveyor of the 4-stand mill. Coils are taken off of the 4-stand mill by conveyor and transported into No. 2 coil storage. From No. 2 coil storage they are transferred by car and tractor to the annealing building.

Figure 1 — Layout of cold reduced sheet mill built by Youngstown Sheet and Tube at Indiana Harbor in 1953.



After annealing they are transferred back to No. 2 coil storage to cool. Coils are loaded on entry conveyor of temper mills by crane. After temper rolling, coils are carried by conveyor to No. 1 coil storage. Coils are entered on shear lines by crane, and packs of sheets are delivered direct to warehouse by conveyor from delivery end of shear lines.

The main substation, which houses the 2300-volt transformers and switchgear, two 440-volt unit substations and two mercury arc rectifiers with their feeder breakers, is located as near the center of the load area as possible.

The outdoor substation and its switch house is located near the back of the property, where it will not interfere with future expansion.

Power is brought into the outdoor substation from the public utility at 34.5-kv (Figure 2). There are two incoming lines, which are run underground in single conductor oil filled cables. All cables are fireproofed wherever exposed.

Each of these feeders is brought into the outdoor sub through an incoming line oil circuit breaker, which is equipped with motor operated disconnects on the line side, and manually operated disconnects on the load side.

The load sides of both incoming line breakers are tied together through an oil circuit breaker that is

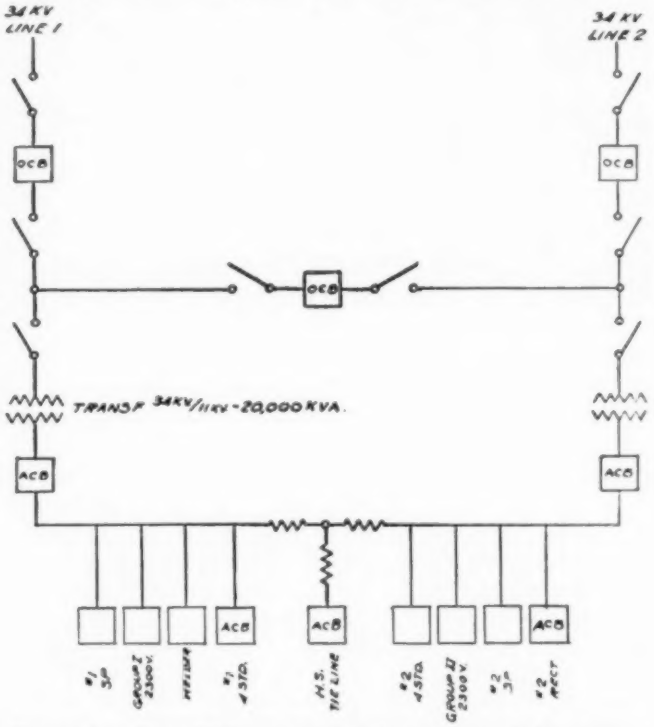


Figure 2 — Two 3500-volt transmission lines bring power from public utility to plant.

equipped with manually operated disconnects on each side.

Each line feeds a 34.5/11-kv transformer through a set of manually operated disconnects. This provides a very versatile arrangement whereby any part of the equipment can be readily isolated for safe routine maintenance or emergency repairs.

The secondary side of the main power transformers are each tied to a section of metal clad switchgear in the switch house through an air circuit breaker.

All 11,000-v distribution cables are 15-kv, 3/c, 500 mcm paper insulated, compact sector shielded, lead covered. They are all run underground in non-metallic ducts, or on cable racks through basements. We believe this underground distribution system has a distinct advantage due to the fact that we have very few outages due to storms or any other disturbance. They are all fireproofed wherever exposed. Also, all manhole designs are of the octagon shape thus permitting us to enter a duct run at any angle for ease in pulling the cable.

There is an emergency tie to the hot strip mill, which can be used to feed power in either direction as needed. This feeder is of sufficient capacity to carry 30,000 kva. With this arrangement it is possible to run the

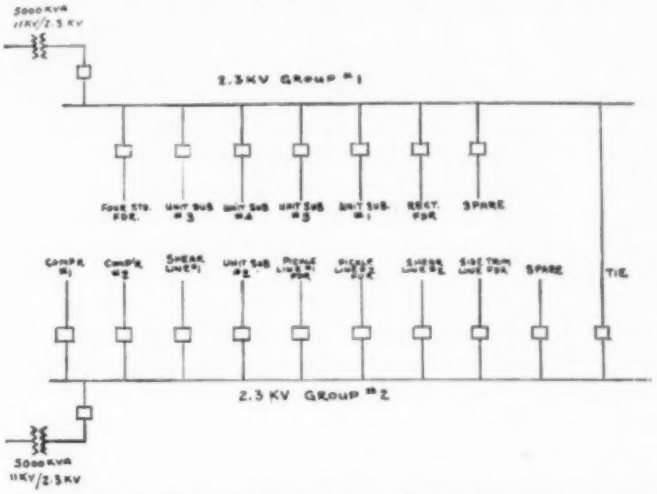


Figure 3 — Main substation has two 5000-kva transformers each of which feeds a section of metal clad switchgear.

entire sheet mill over the tie circuit in an emergency, provided there is enough power available from the other source.

It is also used to good advantage when doing routine maintenance on the outdoor sub. On week ends, the entire mill can be fed over the tie and all outside power equipment can be killed for a safe and thorough job of routine maintenance.

At the present time, we have surplus transformer capacity at the sheet mill, and it is occasionally desirable to feed power out to other parts of the plant through the hot strip tie.

There are two 5000-kva transformers in the main substation. Each feeds a section of metal clad switchgear equipped with air circuit breakers (Figure 3). There is an emergency tie between the two sections of switchgear that can be used if trouble develops in either transformer.

All line breakers for 2300-volt motors are located in the main substation and are remotely controlled from a location near the motors.

All 2300-volt feeders are run in 5 kv, 3/3, V. C. lead covered cable, and are run underground.

The 440-volt system is split up into 5 sections (Figure 4) and each is fed by a 2300/440-volt unit substation. The unit subs are placed as close as practical to the center of the load area they are to serve.

The starting equipment for individual motors is grouped in load centers which are located in motor rooms, control houses, etc., through the plant.

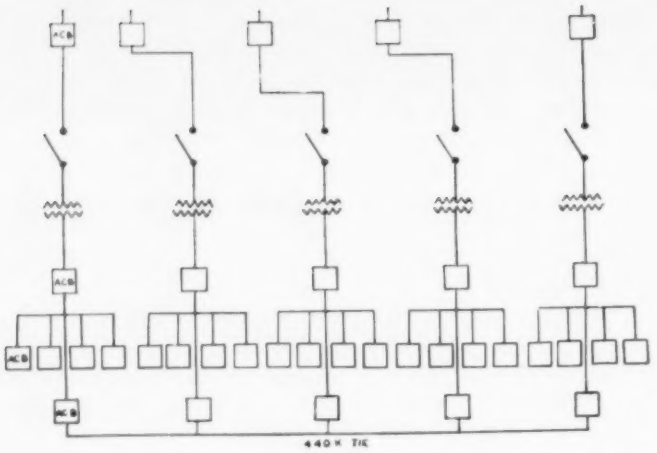


Figure 4 — The 440-volt system is split into five sections.

There is a tie breaker in each unit sub, and these are all tied together by cable. In case of an emergency, partial service can be maintained by tying two sections of feeder breakers together on one transformer.

The 250-volt, d-c system is supplied by two 1000-kw mercury arc rectifiers. Each rectifier has its own section of metal clad switchgear equipped with single pole air circuit breakers. There is a bus tie between the two sections of bus that can be closed in an emergency to maintain full operation in event of a rectifier failure.

All d-c feeders are run underground in 2/c rubber-insulated lead covered cables.

DESIGN CONSIDERATIONS

The general problem in the electrical installation at Youngstown Sheet & Tube Co.'s, Indiana Harbor Works new sheet mill, was that of expansion. Like most expansions, there was the problem of coordinating with the existing system. This was done through the emergency tie to the hot strip mill and happily, in contrast to some mills, the frequency in the existing system in the mill was 60 cycles. The distribution voltage in the other portions of the mill was 11,000 volts, so no problem existed here and no tie transformer was needed.

Power supply—The installation in the sheet mill area was of such a magnitude as to warrant a completely new tie with the utility. This had the definite advantage of giving the Youngstown plant another source of power into the mill in event of major trouble at an incoming power substation. The relaying on the new incoming substation was discussed with the utility and coordinated with the relaying on the other utility tie to this plant.

33-kv equipment—Two main power transformers were installed in this outdoor substation. Each of these was rated 20,000-kva, 3-phase, 60-cycle, was oil-insulated, and self-cooled. The voltage was 33,000 volts delta, with two plus and minus 2½ per cent full capacity taps, down to 11,000 volts delta. High altitude bushings, rated 34.5 kv were installed. Each of these transformers was large enough to supply the mill requirements under emergency conditions. An outdoor steel structure was installed together with three oil circuit breakers of the outdoor frame mounted type, each rated 1200 amp continuous current, 1,500,000-kva interrupting, and these also have 34.5 kv high altitude bushings. These bushings were selected on the outdoor equipment to furnish extra creepage and minimize possibility of flashover, due to possible dirt depositing on bushings between cleanings. The function of the three oil circuit breakers was to feed power from either of the utility's two incoming lines at this station to either or both of the transformers. Sufficient disconnect switches were installed to isolate either the transformers or the oil circuit breakers for maintenance or repair. Differential relaying is installed for these power transformers and on all other transformers throughout this new mill. See Figures 5 and 6.

In the switch house, an indoor metering and relaying board was installed to control this outdoor substation. It was complete with relays, control switches, and a mimic bus (Figure 7).

11-kv distribution switchgear arrangement—The selection of the transformer secondary voltage of 11,000 volts, 60 cycles, 3 phase, was governed primarily by the existing voltage in other portions of this plant to which this distribution system in the sheet mill would be tied. This is a good voltage in relation to the large motors which were installed, and also for distribution to substations throughout the mill. It is an economic voltage relative to standard 500-mva, metal-clad switchgear with 1200 and 2000 amp current ratings. An 18- unit group of indoor 11,000 volts metal-clad switchgear was installed. This switchgear feeds two 11,200-hp synchronous motors, two 2000-hp syn-

Figure 5 — Outdoor substation has two 20,000-kva, 3-phase, 60-cycle, 55 C rise transformers.

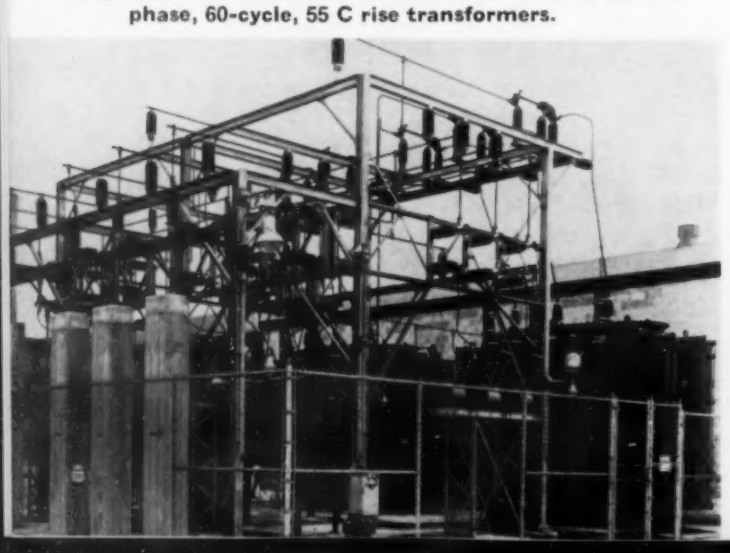
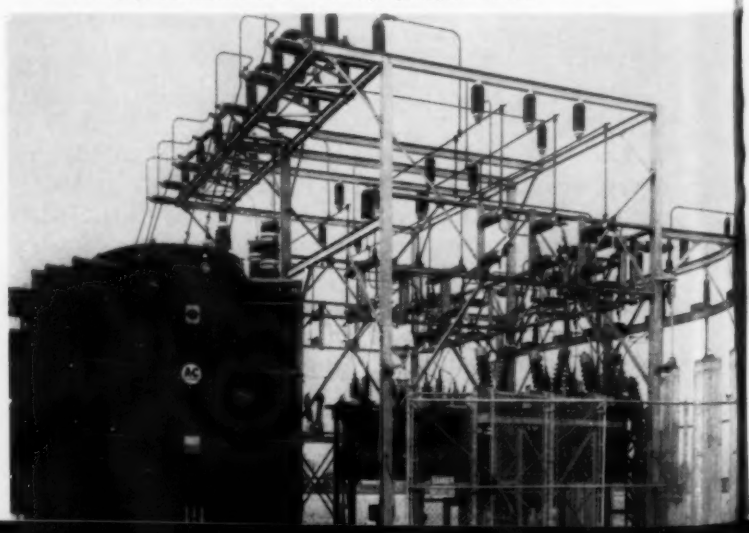


Figure 6 — Transformers have inert gas pressure system. They are connected 33,000-delta-11,500-delta, 1200-amp. Substation has outdoor circuit breakers rated 1200 amp continuous current, 1,500,000-kva.



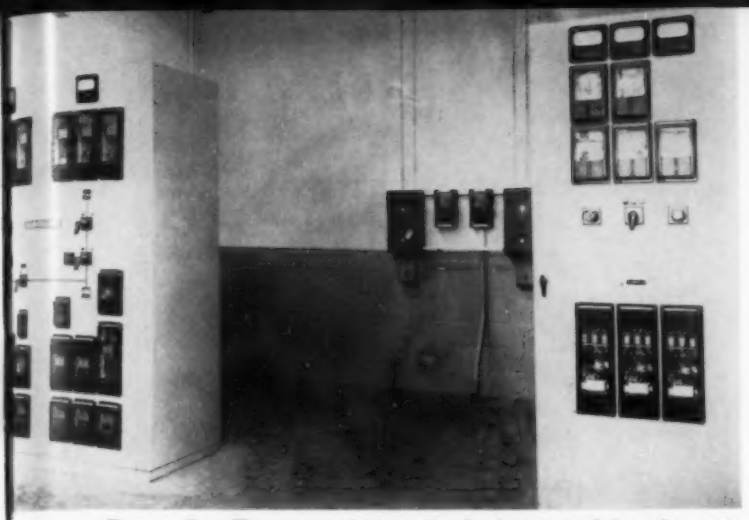


Figure 7 — The metering and relaying panel for the outdoor 34.5-kv oil circuit breakers is shown in the switch house.

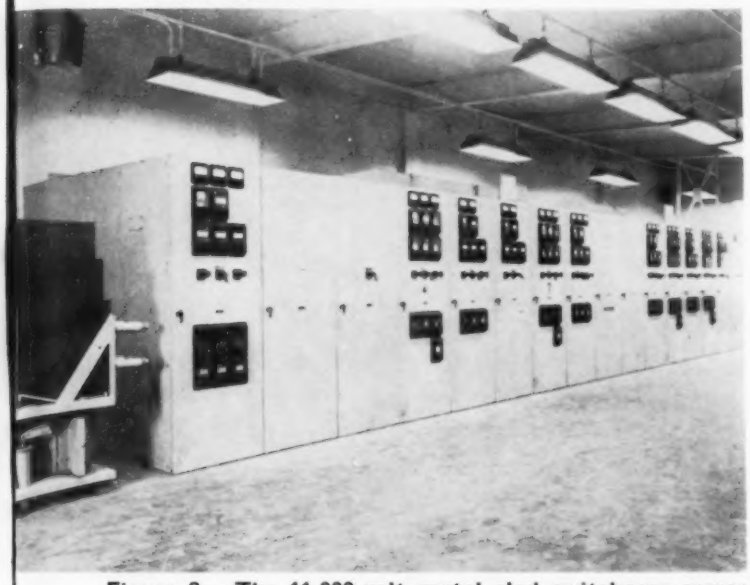


Figure 8 — The 11,000-volt metal clad switchgear serves the main mill motor-generator set.

chronous motors, two 5000-kva substations, a 1500-kva and a 1000-kva load center substation, a 1000-kw rectifier, a 1250-kva welding transformer, a tie breaker to No. 2 tin mill and a tie to the hot strip mill. Both of the 20,000-kva transformers feed directly to the main 2000-amp bus in the metal-clad line-up of switchgear. This was done to obtain the good load factor possible by the use of one main bus, and the loads on either side of this bus are fairly well balanced.

Duplex reactor—A cooperative short circuit study was made on an alternating current network analyzer and this indicated the need for placing a current limiting reactor in the emergency tie to the hot strip mill. The short circuit characteristics of this system also made it necessary to split the main bus in the 11,000-volt switchgear by means of a current limiting reactor. Study of the problem indicated that this was an ideal application for a duplex current limiting reactor. The two sections of the metal-clad switchgear bus are tied together by a duplex reactor and a standard reactor is tapped off from the mid-point of the duplex reactor to limit the fault on the emergency tie to the hot strip mill. The wye connection made with the duplex reactor and the standard reactor, resulted in a saving in cost, space, and installation work, over what would have been encountered if standard reactors had been used (Figure 8).

Large motor controls—All motors of 2000 hp and over are operated on 11,000 volts. Motors from 200 to 2000 hp are fed from the 2300-volt system. The starting equipment and field application panels are located in the mill as near as practicable to the motors they serve. These panels are metal-enclosed and have mounted on them an a-c voltmeter, an a-c ammeter, a d-c field ammeter, a circuit breaker control switch and indicating lights, a thermal relay and a temperature indicating instrument.

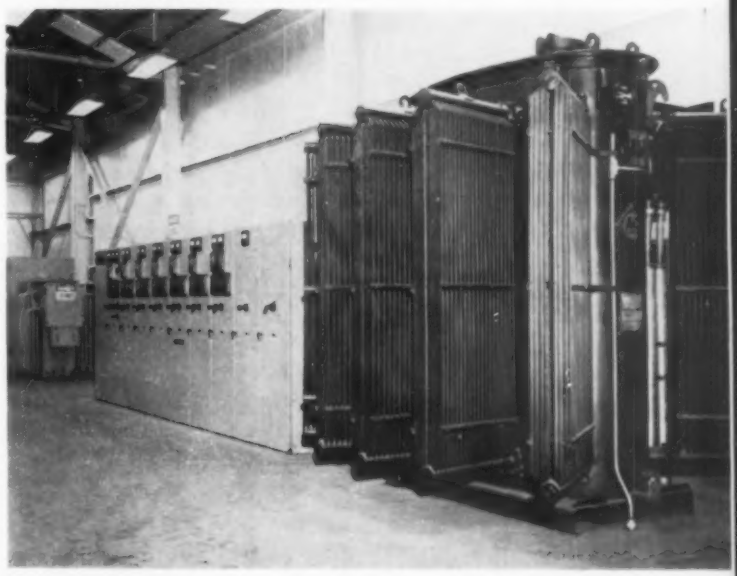
Automatic power factor control was installed on the two 11,200-hp synchronous motors. It was considered economic to control the power factor of these two large motors. The control is of the static-type using magnetic amplifiers. The installation provides for automatic power factor regulated excitation, with maximum and minimum excitation limits or for manual self excitation.

Each regulator consists of a two-stage, 3-kw, magnetic amplifier supplying a direct connected motor field exciter which is equipped with a small bucking field. The two regulators are packaged complete with the selenium rectifier reference power supply in a ventilated steel cabinet. The packaged type construction reduces maintenance and inspection to a minimum.

The larger motors were all started by the use of reduced voltage starting by means of a neutral reactor and neutral reactor shorting breaker. The circuit breakers in the 11-kv and 2.4-kv switchgear groups are air-magnetic type, rated 500 mva, and 150 mva respectively. The relaying and metering used throughout was in accordance with accepted practice and NEMA standards. Differential relaying and surge protection equipment was installed on all 11,000 volt motor circuits. The 11,000 volt system is well grounded and feeder ground relays are used.

2300-volt and 440-volt substations—The selected 2300 volt system is a good choice for servicing intermediate size motors when the distance involved in the cable runs to the motors is not too great. Therefore, two 5000-kva, 2300-volt substations were installed in a

Figure 9 — The 5000-kva substation has 3-phase, 60-cycle, 55 C rise, sealed tank construction connected 11,000-delta to 2300-delta.



substation building. This building was placed at the electrical load center and serves a dual purpose as power is fed to various motors and to five 1000-kva load center substations (Figure 9).

Motors below 200 hp are serviced from one of the seven 480-volt substations. Air circuit breakers are used on all of these load center substations (Figure 10).

The two 5000-kva transformers, the six 1000-kva load center transformers, the 1500-kva load center transformer, and the 1250-kva welding transformer were all insulated with non-inflammable liquid to obtain higher impulse levels and withstand atmospheric contamination while eliminating the possibility of fire hazards. Non-inflammable liquid-immersed disconnect switches were used on the primaries of the load center transformer substations (Figure 11).

D-c general shop and crane supply—D-c power for general shop use and crane supplies is furnished at 250 volts by two 1000-kw rectifier units. The nominal 250-volt rating being chosen to provide the maximum practical personnel safety and still stay within reasonable distribution copper sizes.

As mentioned previously, the a-c power for the rectifiers is taken from the multiple unit, metal-clad a-c switchgear. A separate breaker supplies each rectifier unit. From the a-c switchgear, power is fed to dry-type self cooled rectifier transformers with a nominal rating of 1200-kva each.

The rectifier transformers are wound for rectifier service with the secondaries connected for six-phase, double wye with interphase per ASA connection No. 45. This connection offers the best utilization of transformer copper, reduces peak currents of the rectifier tubes and provides a relatively smooth d-c output.

The transformers are located adjacent to the rectifier frames which allowed the anode connections to be made directly to the rectifier tubes by means of overhead bus. Since this overhead bus was made a part of the rectifier unit, no expensive installation was required.

The d-c output from the rectifiers is carried underground, by cable, to two multiple unit metal-clad switchgear sections, one for each rectifier. Each section contains a cathode breaker and eight feeder breakers. Included in the switchgear line-up is provision for tying the two rectifiers together. This was accomplished by adding a tie section to one set of rectifier switchgear and making provision in the other for connecting the tie cables.

All d-c breakers are rated at 150,000-amp interrupting capacity, are of the drawout type and are equipped with a negative disconnecting device which allows complete circuit isolation when the breakers are in the test or draw out position. For purposes of interchangeability, all feeder breakers are of the same rating, thereby making it possible to substitute a breaker from a less critical circuit during maintenance or repair.

The rectifiers and their associated components are equipped with automatic or semi-automatic type controls. With the auxiliary control switches set to "automatic" it is only necessary for the operator to close one master switch to place the respective unit in service.

The operation of this master control switch will place all needed auxiliaries in operation, followed by the closing of the a-c breaker and then in sequence the cathode breaker and feeder breakers. Load measuring, automatic reclosing is provided on all feeder breakers. Magnetic amplifier type voltage regulators provide

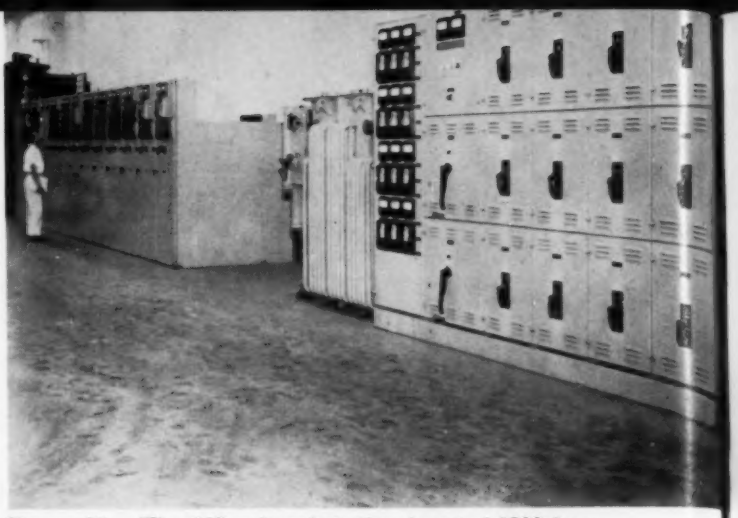


Figure 10 — The 440-volt substation is rated 1000-kva.

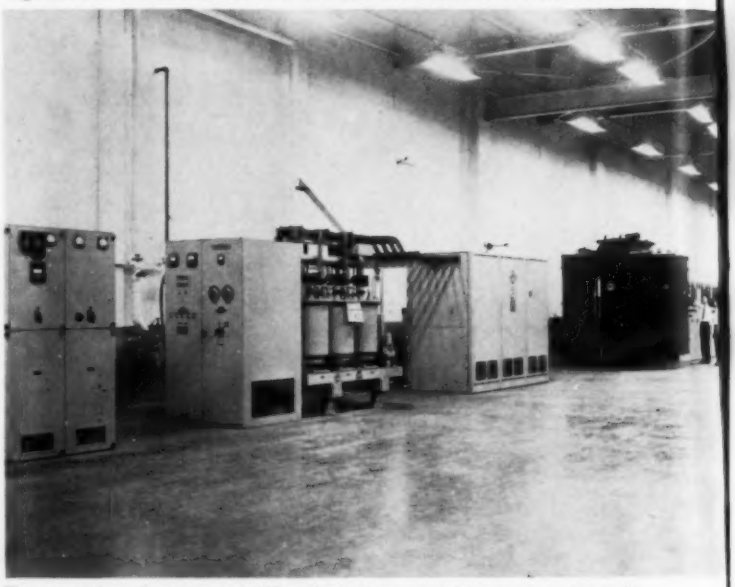


Figure 11 — In sheet mill substation can be seen from left to right: 1000-kw rectifier, 5000-kva transformer, 2300-volt switchgear, and a 1000-kva low voltage substation.

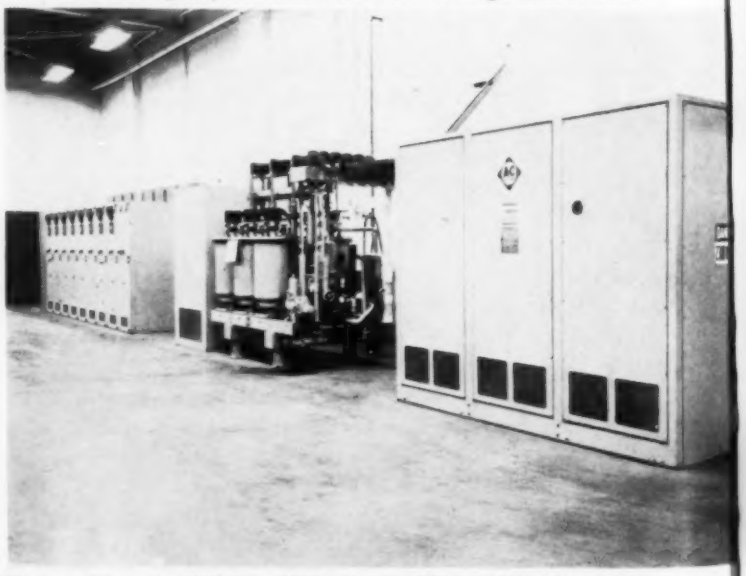


Figure 12 — A 1000-kw, 250-volt rectifier with dry type transformer serves as shop supply to main sheet mill.

essentially constant output voltage up to the rating of the rectifier.

Protective features are provided which will cause either temporary or permanent shutdown of the units depending on the degree of the trouble. Other protective interlocks prevent starting the rectifier if any auxiliary device should not start or be operating properly.

Annunciators are provided to indicate the source of faulty operation.

The rectifiers themselves are of the heavy duty pump-evacuated type, suitable for the rugged duty so often encountered in steel mill service. Six water-cooled tubes are used for each rectifier. Treated distilled water is used in the closed circuit through the tubes and general mill water through the heat exchangers. This system allows poor quality water to be used for dissipating the heat losses without adding to the room heat load (Figure 12).

A heavy-duty battery was selected for control power purposes because of a battery's dependability. A potential of 250 volts d-c was selected so that the shop supply could be used in emergencies and also there is less IR drop in control wiring when 250-volt control is used.

A point of interest was the carrying to a central load dispatcher the watts of the incoming lines, where they were totalled with those of the other two incoming lines from the utility. The load dispatcher supervises a half-hour cumulative demand meter. He also has on hand, a graphic watt-hour meter showing the input to the four-stand tandem mill.

DISCUSSION

PRESENTED BY

J. F. HEADLEE, General Supervisor, Electrical Engineering Dept., United States Steel Corp., Fairless Works, Fairless Hills, Pa. (At time of paper presentation. Now with A. G. McKee & Co., Cleveland, Ohio.)

E. A. YOUNG, Superintendent of Maintenance, Sheet and Tin Mills, Indiana Harbor Works, Youngstown Sheet and Tube Co., East Chicago, Ind.

PAUL THANOS, Assistant Superintendent, Power Steam & Combustion Department, Inland Steel Co., East Chicago, Ind.

S. L. JAMESON, Electrical Engineer, Construction Engineering Division, General Electric Co., Schenectady, N. Y.

A. J. WHITE, Application Engineer, Steel Mills Systems Application Engineering Section, General Electric Co., Schenectady, N. Y.

FRANK NOLAN, Switchgear Engineer, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

A. D. MILLIKIN, Rectifier Engineer, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

J. J. SILECK, Electrical Engineer, The Dow Chemical Co., Madison, Ill.

J. F. Headlee: 1. Referring to the 34.5-kv service lines, (a) are these lines owned and maintained by the public utility or by the consumer? (b)What measure to maintain an equal and adequate static head of oil in the cable has been provided? (c)What factors indicated the underground versus aerial service?

2. Referring to the d-c feeder system, Mr. Young should be congratulated for his wisdom in using lead-covered cables but what factors substantiate the first cost versus other less expensive cable installations?

3. Referring to automatic power factor control for the two 11,200-hp synchronous motors, does this system regulate only the motor power factor, or does it regulate bus power factor, that is, all loads served by the bus?

4. Referring to the 11,000-volt system being well grounded, how many ohms, what circuit connections and what type of ground or earth electrodes were involved?

5. Referring to transformer insulations, why was non-inflammable liquid used on the two 5,000-kva transformers and others, whereas air insulation was used on the two 1,200-kva rectifier transformers?

E. A. Young: 1. The 34.5-kv service lines are owned as far as our property line by the public utilities company and are maintained in their entirety by the public utilities company. Oil tanks near the top of the manhole are used to maintain adequate static head of oil in the cable. All of our experience here in the plant has been with underground power feeders with which we have had very good results. Therefore, we are not in a position to compare the underground versus the aerial service.

2. On the feeder system, we feel that lower maintenance costs and less power outages overcome the greater first cost of lead cable.

3. The automatic power factor control, controls only the two 11,200-hp synchronous motors.

4. We have six ohms in our ground circuit and the earth electrodes are heavy copper plates buried in coke breeze below the motor room basement floor.

5. For many years in the past, it has been our practice to use non-inflammable liquid for cooling all indoor transformers. However, in some cases in recent years we have tried out larger size air-cooled transformers.

Paul Thanos: I am particularly interested in the underground distribution. At the Indiana Harbor Works of Inland Steel Co., we have gone just the other way and used all overhead distribution, utilizing weather proof insulation on overhead lines and thereby minimizing the installation costs. Our experience has been that by the use of proper ground wires, lighting arrestors and surge capacitors, we have very few production delays caused by lightning or any other electrical faults.

I have one additional question. What advantages are there to the pump type rectifier over the vacuum seal type rectifier that caused you to buy that type?

E. A. Young: The pump type rectifier had been used longer than the vacuum seal or pumpless type, and at the time we felt we should try the rectifier that had the most use in industry. However, at the present time we are considering purchasing the vacuum seal or pumpless type.

S. L. Jameson: We recently installed a coid mill distribution system which was similar in overall arrange-

ment to the installation described in the paper. Floor space was at a premium, and all the substations were therefore installed on balconies on the building column lines. The location of these balconies was carefully selected for central location for power distribution and so the overhang was in areas where floor space was not at a premium and was preferably used for an aisle. Processing lines ran at right angles to the building column rows and passed under two of the balconies.

This installation was rendered still more flexible through use of interlocked armor cable through the roof trusses for tie lines and for principal feeder lines on both 440-volt, a-c and 250-volt, d-c circuits. Three conductor cable was used for 440-volt, a-c; and 4/c cable was used for 250-volt, d-c paralleling two of the conductors positive and two conductors negative.

A. J. White: I would like to ask the authors a few points regarding certain details of the power distribution system:

1. Mr. Nolan, in his portion of this paper notes that the 11,000-volt system is well grounded and that feeder ground relays are used. I would like to ask Mr. Nolan how the system neutral was obtained and what type of grounding impedance was used at this voltage level? I would also like to ask the authors what grounding treatment was given to the 2400-volt and 480-volt systems?

2. The authors in the paper note that a duplex reactor was used to tie the cold mill bus to the hot strip mill. I would like to inquire what switching means were provided for the duplex reactor?

3. From the author's paper, it would appear that the a-c load center unit substations were connected both to the 2400-volt switchgear bus and some were also connected to the 11-kv switchgear bus. I would like to ask the authors what factors determined the point of connection of these 1000-kva, a-c load center unit substations?

Frank Nolan: The answers to these questions are as follows:

1. The system neutral was obtained by connecting our 11,000/2300-volt transformer bank, wye delta and the neutral taken off of the wye common point of the connection on the primary side of the transformer through a grounding breaker and through 6 ohms of resistance to ground. We have no grounding on our 2400 or 480-volt systems.

2. The duplex reactor in our cold mill bus to the hot strip mill is connected solid to the bus with the tie to the hot strip coming off the center point of the reactor through breaker. We have found from experience that it would be a definite advantage to have isolating switches on both ends of the reactor.

3. The primary voltage on unit substation is usually determined by the power available. We prefer 11,000 volts when practicable. In this case it was a question of delivery on equipment.

A. D. Millikin: Mr. J. F. Headlee has raised the question of why the two 5000 kva transformers were of the non-inflammable liquid type whereas the two 1200-kva rectifier transformers were air insulated.

This selection was actually a customer preference. Apparently Youngstown had been trying out air-insulated transformers for several years with very good success and decided to apply the air insulated dry type to the rectifiers.

It has apparently been the experience of Youngstown, like many other users, that the dry type requires very little attention other than blowing dirt from the coils at suprisingly infrequent intervals and results in very low overall maintenance costs.

Mr. Paul Thanos has asked the advantage of the pumped type rectifier over the sealed type that led to their choice for this application.

Pumped type rectifiers have been used for many years for rugged heavy duty applications and have been well proven for their reliability. The sealed type are relatively new and enough operating experiences had not been gained to fully evaluate their qualifications for heavy duty type applications such as required by steel mills.

The question of maintenance, down time and spare part inventories has always been an item that cannot be overlooked by operating personnel. Pumped rectifier tubes offer the distinct advantage of quick field repair with a bare minimum of spare parts required on hand. Tube repair is relatively simple and can be handled by ordinary maintenance men such as employed in the mills.

Recent developments in the art of making vacuum seals has greatly simplified the ease with which bolted type vessels (tubes) may be made vacuum tight. Due to the increased tightness the useful life of the rectifier tubes has been lengthened before reconditioning is required.

The modern vacuum pumping systems have been well proven, as borne out by user surveys to require extremely low maintenance. The continuously pumped system, in addition, offers the distinct advantage that the tube vacuum is under continuous observation and its proper degree maintained at all times regardless of the operating conditions.

J. J. Sileck: About four years ago, while electrical engineer at the Indiana Harbor Works, the electrical design specifications were written in complete detail including the number of feeders, transformer ratings, metering, protective devices, front viewer arrangements, and single line diagrams. These details expressed the desires of the men at the plant for reliability and flexibility. The completed system is as originally proposed except for the incoming power source and location which were not determined at the time.

The growth of the plant had established a distribution pattern which employed 2300 volts, 11,000 volts, and 440 volts, a-c and 250 volts, d-c for generation, distribution, and utilization. The 250-volt, d-c was not selected for economy of copper, but had been an established voltage for cranes and mill auxiliaries since the plant was established.

The original 2300-volt distribution was underground and this pattern has been followed where possible.

The pump type 250-volt, mercury arc d-c rectifiers were selected because of the operating experience compared to the sealed tube units at the time.

Askarel filled transformers were selected for indoor installation as well as for protection of the windings from atmospheric conditions.

These comments relate to the original design of this power system prior to its manufacture and operations.

If developments in steel extrusion make the same progress at the same pace in the future as they have to the present, then there is no question that the industry is at the dawn of a new day in steel application and usage . . . . the process, still not fully developed or exploited, cannot compete with rolling mills for production of large quantities of standard steel sections, but it is a specialized tool, particularly suitable for small orders and complicated sections.

Figure 1 — Overall view of the new hot extrusion plant shows in foreground the automatic billet cut-off machine. Back of it is the induction heating furnace. The hydraulic extrusion press is located at the right. Runout table and cooling beds can be seen in rear center. To the rear left center is the stretcher-detwister. The equipment in the far upper left is the shot cleaning machine.

Hot Extrusion of Carbon Steel Solid Sections

By JOSEPH K. SEYLER

Superintendent, Hazelwood Cold Finishing Dept., Jones & Laughlin Steel Corp., Pittsburgh, Pa.

▲ IN recent years, increasing attention has been focused on the hot extrusion process. During World War II, and the period immediately following World War II, the principal interest centered around the hot extrusion of aluminum, magnesium, and the so called "red metals." The hot extrusion of steel is the latest development in this field. It is this process and more particularly the hot extrusion of carbon steel solid sections with which we are concerned in this paper.

The term extrusion may be defined as "the act of expulsion by mechanical force." Probably the simplest example of extrusion is the squeezing of tooth paste out of a tube. Essentially the process is one by which a block of solid metal is converted into a continuous length of uniform cross-section by forcing it to flow, under high pressure, through a die orifice which is so shaped as to impart the required form to the product. In the main it is a hot marking operation, the metal being heated to give it a suitable degree of plasticity.

Hot extrusion is not a new process. The earliest development on record was a patent granted in 1797 covering a method of extruding lead pipe. Shortly after 1800, hot extrusion became the accepted method for processing lead and some lead alloys. Initially, the process was limited to soft alloys with low melting points. However, continued work with the process eventually made it available for aluminum and the red metals such as copper, brass, and brass alloys. In the last thirty years, great strides have been made in the non-ferrous field, principally due to the development of large presses, and tools capable of withstanding high pressures and temperatures.

Metallurgists and operators have long been intrigued by the possibility of using the hot extrusion process

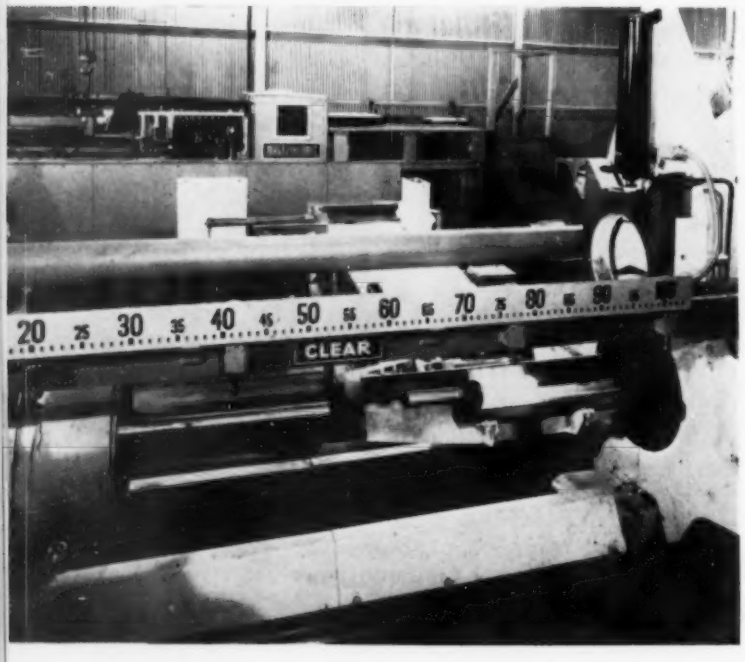
for steel. Experiments in this field have been going on for many years. It remained for a young Frenchman named Jacques Sejournet to make the key contributions which have made hot extrusion a feasible process for steel. It was he who developed the so called "Ugine-Sejournet" glass lubricant process, the process which is currently being used by the steel extruders in this country. While the extruders in this country have made definite improvements to the process, at the present time they are still operating under the French owned patents.

Initially the hot extrusion of steel in this country was limited to the production of thin wall alloy tubes. However, in the past several years, considerable work has been carried on with the extrusion of solid sections. The process as used by Jones & Laughlin Steel Corp. is to hot extrude solid carbon steel sections which are subsequently further finished by cold drawing.

The process as presently employed requires either 4 or 5-in. round billets for the press. The choice of billet sizes was predicated on the fact that it was thought commercially desirable to extrude sections having a weight per foot range of one-half to twelve lb per ft. The billets are prepared from hot rolled 4 or 5-in. rounds which have been descaled by pickling. They are then cut to billet length in an automatic cut-off machine which simultaneously chamfers a $\frac{3}{4}$-in. radius on the leading end. Billet lengths vary from 4-in. diam by 5-in. long to a maximum of 5-in. diam by 20-in. long. The billet length is determined by the extrusion ratio of the section and the desired length of the as extruded product.

Heating of the billets is accomplished in a triple coil, two-stage, sixty-cycle induction coil type billet heater of special design which employs helium under low pressure as a protective atmosphere. Each heating coil is provided with a radiation pyrometer focused on the billet for temperature indication and connected to a temperature recorder and controller. This unit is capable of heating carbon steel billets from room temperature to 2300 F at the rate of 4000 lb per hr.

Figure 2 — Ram of the 1000-ton horizontal press is moving toward the white hot glass-coated billet which will be squeezed through a die producing the extruded section. Numerals on the rule, calibrated in inches, indicate ram travel.



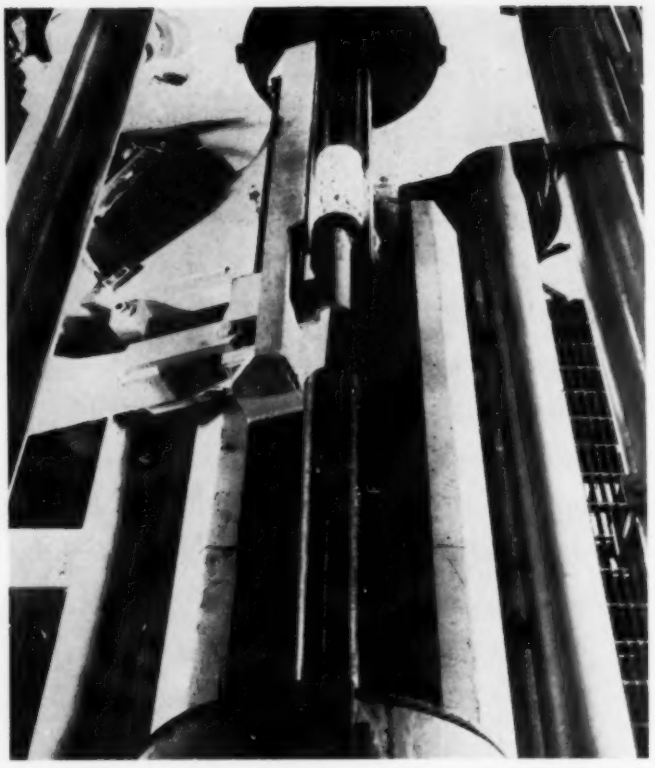


Figure 3 — Overhead view shows press ram advancing toward hot billet ready for extrusion.

Extrusion is performed on a four-column, horizontal press of 1000 tons capacity, and with a 100-in. stroke. A mandrel moving device is built into the main ram and the press is suitable for the extrusion of both solid and hollow sections. The press is a single cylinder machine with an inserted forged steel main cylinder, and has hydraulically operated container movement, die holder carrier movement, and die lock. Auxiliary equipment includes two hydraulically operated high speed saws, a mechanized billet and dummy block loading arrangement, and a device for separating the butt end from the dummy block. A swinging die arm facilitates placement and removal of dies, and permits die changing during the ejection cycle. An air driven brushing mechanism automatically positioned, cleans the container between extrusions. This press is capable of 60 extrusion cycles per hour.

A typical extrusion cycle starts with the placing of the die into the die platen with the press in the open position. The press is then closed and a glass lubricating disc is placed in the container adjacent to the die opening. A heated billet is then ejected from the billet heater onto a gravity feed table which is covered with powdered glass. The billet in traversing the table picks up the powdered glass which becomes molten on contact. The billet rolls onto a billet loading mechanism which also carries a pre-positioned dummy block. Billet and dummy block are loaded into the press container, after which the loading mechanism returns to position at the end of the heater feed table. The main ram is brought forward and contacts the billet. A low pressure pre-stroke upsets the billet after

which the actual extrusion takes place under high pressure. The section is extruded onto a delivery table after which the press is opened. With the press in the open position, the section is parted from the discard by means of a high speed saw. The press is closed again to push the parted section through the die after which the section is removed to the hot bed for cooling. The press is re-opened and the dummy block, to which the discard has become attached, is ejected, the container is cleaned, and the press is readied for the next cycle. In operation from 4 to 12 dies are used in rotation, the exact number depending on the quantity to be extruded. A number of dummy blocks are also used to permit air cooling between cycles.

After cooling, the sections are straightened on a 50-ton hydraulic stretching and detwisting machine. On this machine, both head and tail stocks are of a hollow head design to permit localized detwisting. This straightener has a stretching capacity of 100,000 lb, and a stroke of 60-in. on the head-stock cylinders. It is capable of handling bars of a size that can be contained in a 4-in. diam circle, and in lengths up to 50 ft. Rotation of the detwisting head is unlimited in both directions, and stretching speed is adjustable up to 55 fpm.

Removal of the glass remaining after straightening is accomplished in a shot blast unit. The wheel units are mounted above, below, and to either side of the pass line of the work in order to clean the entire periphery of irregular cross sectional bars. A work conveyor carries six bars at a time through the units at speeds from 15 to 45 fpm. The steel shot is reclaimed, cleaned, and recycled through the process.

In general, it is possible to extrude any steel that can be rolled. In addition, some steels and semi-steels that cannot be rolled can be processed by hot extrusion. Theoretically, it is possible to extrude any shape for which a die can be made. Actually there are some practical limitations such as very sharp corners, thin fins, and small inside radii. However, by a combination of hot extruding and cold drawing, the variety of sections obtainable is virtually unlimited.

Steel extrusions enjoy a high reputation both in regard to their standard of quality and their good physical properties. The physical properties, in some cases, are superior to those obtained in other wrought forms. Steel extrusions normally have a high order of homogeneity, less directionality than rolled sections, and transverse properties are practically equal to the longitudinal properties. Internal quality can be very good, and extrusion surfaces are usually superior to rolled surfaces. The close size accuracies obtainable with extrusions are one of the outstanding characteristics of the process.

In any consideration of the place that the hot extrusion process will take in the steel industry, it should be borne in mind that it is definitely not in competition with rolling mills for the production of large quantities of standard steel sections. It is rather a specialized tool which materially opens up the vista of our possibilities. Some of the ways in which the process may be used to economical advantage can be summarized as follows:

1. Processing materials that cannot be rolled, or are very difficult to roll.

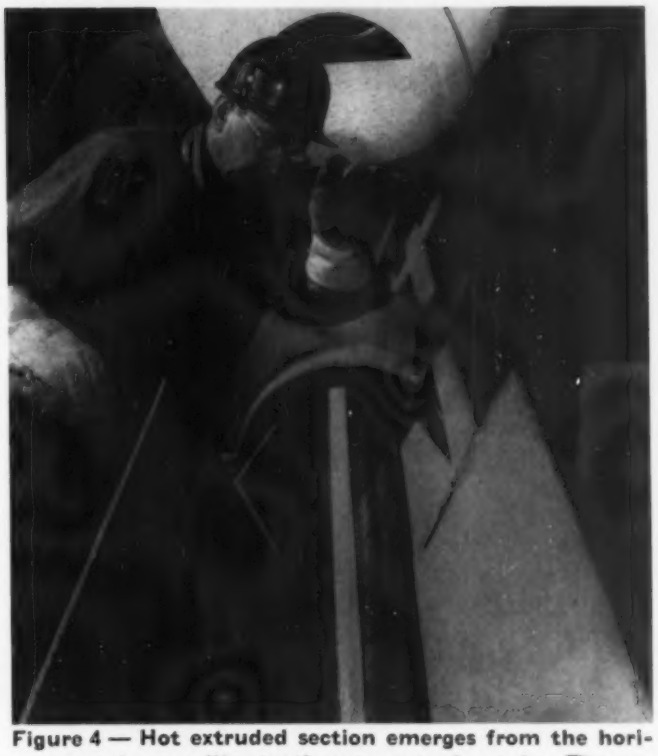


Figure 4 — Hot extruded section emerges from the horizontal press like toothpaste out of a tube. The extrusion is produced in a matter of seconds.

2. Producing small quantities insufficient to warrant setting up a rolling mill. (This application is becoming more important with the scrapping of small hand mills in favor of the large, high production mills.)
3. Executing rush orders, when the quantity is limited. (An extrusion press is quite versatile and can be set up in a very short time if proper dies are available.)
4. Producing sections that are impossible or impracticable to roll. In this case, hot extrusion, in conjunction with cold drawing, can be used to advantage to produce exceptionally complicated sections. While the final cost may be high, the section may represent practically a finished part and save the consumer considerable very expensive machine work. In this application, hot extrusion is not competing with rolling mills, but with machine shops. The possibilities of this application appear unlimited and it is in this area where we find the greatest amount of the present interest in this process.

It would be completely unfactual to say that this process has been fully developed and exploited because there is much work yet to be done. However, progress made to date is more than sufficient to justify the current interest in this new tool of industry. There is currently considerable research and development work under way with this process, and undoubtedly much in the way of improvement and techniques will result from this work. A widespread program of education in the use of steel extrusion is in progress and the results of this work are already apparent.

If the steel extruders in this country can continue to make progress in the future at the same pace as they have in the last several years, then we are at the dawn of a new day in steel application and usage.

DEVELOPMENT OF CONTINUOUS

By WILLIAM W. JACOBS
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▲ THE continuous casting of metals is not a new concept, although it is only in recent years that it has been successfully accomplished on more than an experimental scale. Over a hundred years ago (1843), the first patent was obtained in this field on a process for continuously casting soft metal tubing around a vibrating mandrel. The idea of producing a finished or semi-finished product directly from the molten state has been a goal of steel men for many years.

In the early 1930's, Siegfried Junghans in Germany developed a method of continuously casting brass which was more successful than any previous method. The Junghans process consisted of pouring molten brass into a water-cooled copper mold, withdrawing it from the mold and cutting off the resultant solidified billets. However, his method differed from other continuous casting attempts, in that he included a means of oscillating the mold during casting. The oscillation is parallel to the axis of the casting, the mold descending at exactly the downward speed of the casting for a short distance and returning at an accelerated rate. This motion results in a stripping action, preventing sticking of the metal to the mold, which had doomed many a previous attempt to failure.

Figure 1 — Filled ladle is being hoisted by crane to casting floor.

In 1938, Irving Rossi obtained the rights to the Junghans process, which is now known as the Rossi-Junghans process. Much of its success throughout the world can be attributed to Mr. Rossi and his associates, who have continually strived to improve its original concept.

In 1949, the first successful attempts to continuously cast steel by the Junghans method were made by Junghans in Germany and by Allegheny Ludlum Steel Co. in America. Since then, other steel machines have been built in Austria, Germany, England, Sweden, Japan, France and Canada.

The first commercial steel casting machine in the United States or Canada is the one at Atlas Steels in Welland, Ontario. Construction was begun in December 1952, when excavation for the billet discharge pit was begun.

The existing building piers had to be replaced to give more height and strength to support an 85-ton crane whose sole purpose is to transport the ladle to and from the casting floor. It has a bridge travel of only 70 ft, and a span of only 25 ft, with the crane rails being 66 ft above ground level.

The building itself is 85 ft high, the casting floor 31 ft above ground level and the discharge pit 20 ft deep. The casting department is adjacent to the melt shop and the molten metal is transported in a covered insulated ladle. Due to the layout of buildings and equipment, it is necessary to transfer this ladle 165 ft on a ladle car and over a turntable to position it under the the crane in the casting department.

The four levels of the machine, from the top down, consist of the casting floor, the spray floor, the machinery floor and the cutting floor. The ladle tilting equipment and the oscillating mold are situated on the casting floor. The spray floor houses the spray chamber where the cast billet is cooled. On the machinery floor are located the main drive motor, the pinch rolls and the oscillating equipment. On the cutting floor are the cutting torches and discharge equipment.

Ladle equipment consists of 8, 14, 30, and 35-ton

CASTING AT ATLAS STEELS, LTD.

. . . . since the original installation of the continuous casting machine at Atlas many improvements have been made . . . . a number of automatic controls have been developed for operation of the equipment, size of original molds has been changed, work has developed information on solidification, and a method has been developed adding aluminum to the mold . . . .

ladles complete with covers. Provisions have been made on the machines to allow for 50-ton ladles in the future. These ladles are the lip pour type and have a specially designed dam to hold back the slag. They have extra insulation in the lining and have insulated covers to minimize heat loss.

The molds for which the machine is now equipped 4¼-in sq, 5½ x 7½-in., 2½ x 17-in., 5½ x 21½-in., and 6½ x 24-in. These molds are 20-in. long and are made of oxygen-free, high conductivity copper. They are provided with vertical passages for cooling water. These passages contain restrictor rods which confine

Figure 2 — A worker is shown cleaning the tundish just prior to pouring in order to remove any small pieces of brick or other material which may have accumulated during the preheating of the tundish.

Figure 3 — In start of pour in continuous casting machine, ladle is tilted and hot metal goes through tundish into mold (below) with its water lines. Note control box in hand of operator.

the water to a 1/16 in. annulus. Cooling water volumes are as high as 300 gpm on the largest mold at a pressure of 60 psi.

The mold is mounted on a mold table which oscillates during casting. The downward travel of the mold is at the same speed as the rate of withdrawal of the casting (three-fourths of the cycle). The upward movement is three times as fast (one-fourth of the cycle). The oscillation is effected by a double lever and cam system. These are driven by the same 15-hp motor which drives the pinch rolls.

The bottom of the mold is formed by a starting bar or "dummy bar." This dummy bar has one or more large-headed bolts inserted in the top to which the first metal cast attaches itself. The dummy bar is supported by two sets of pinch rolls. When the process starts, these pinch rolls revolve, pulling the dummy bar down and with it, the newly solidified bar or slab. The speed of the pinch rolls is synchronized with the mold oscillation. The speed of casting is controlled by the machine operator on the casting floor through a remote control switch. Casting speed can be varied from 0 to 175 in. per min.

From the mold, the bar passes into the spray chamber below and through a roller apron. The roller apron consists of a series of rollers encasing the newly formed billet. It gives mechanical support to the billet, which at this stage, consists of a shell with a molten center and enhances the cooling effect of the sprays. Water is sprayed on the casting through several vertical pipes equipped with various types of spray nozzles. Spray water volume can vary from 30 gpm to 850 gpm depending on grade, size and speed of casting.

From the spray chamber, the bar travels down through the pinch rolls to the cutting chamber. The cutting is done by oxyacetylene powder torches suspended from a torch carriage. The torch carriage clamps to the bar by means of a pneumatic clamp and travels with the bar while the actual cut is being made. When the cut is finished, the clamp releases and the torch carriage returns to starting position for the next cut.

The cut bar, which may be from 8 to 16 ft long, is lowered on a pneumatically operated lowering basket to the discharge carriage. This carriage is situated in a 20-ft pit and is moved up on tracks to ground level by means of a car puller. At ground level, a pneumatic pusher moves the bar off the billet carriage on to a drag chain conveyor, which drops it into a cradle.

An actual casting run begins as follows: five to six hours before the furnace is scheduled to tap, the ladle operator begins heating his ladle. A 4,000,000 Btu per hr oil burner is used for this purpose. The ladle will be heated to 2400 F by tapping time.

In the meantime, the casting machine operator begins setting up the machine. The dummy is introduced approximately 7 in. into the mold from the bottom. The space between the dummy bar and the mold is packed with asbestos to prevent leakage. Lubrication lines are adjusted to give best coverage in the mold by the rapeseed oil which is used as a lubricant between the metal and the mold wall.

A tundish or pouring pot is mounted and centered over the mold. It has been provided with a nozzle made of stabilized zirconia. Prior to casting, the tundish is heated by means of a gas burner to approximately 2450 F to minimize the chilling effect on the first metal cast.

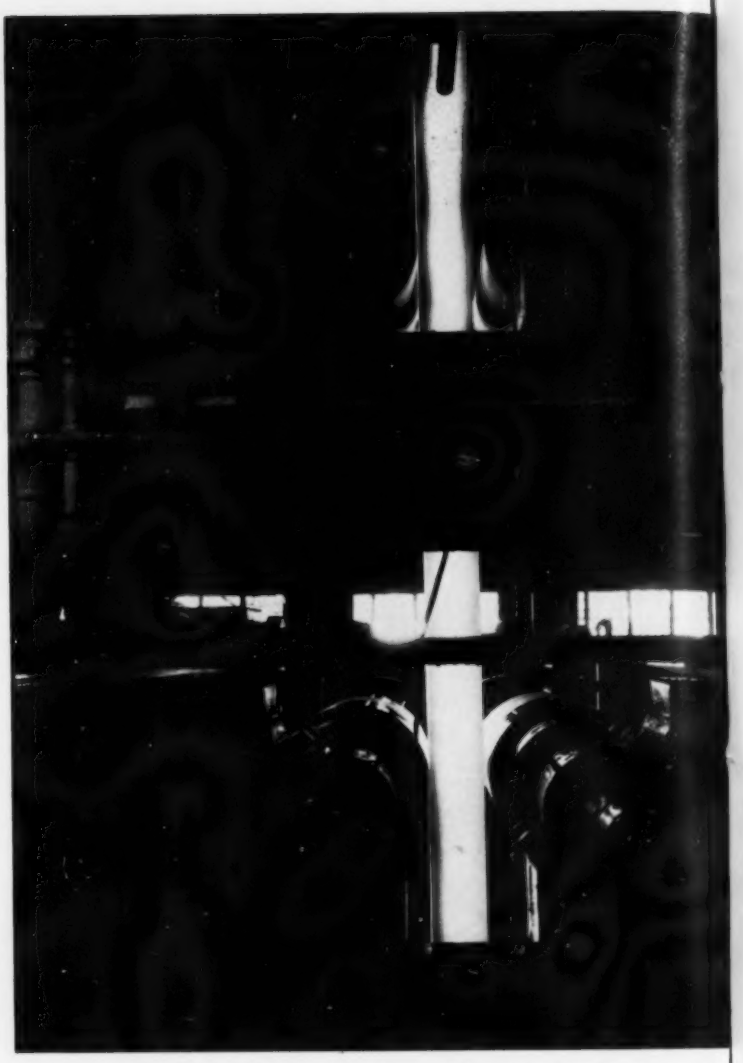


Figure 4 — A slab is being guided down through the pinch rolls, two floors below the casting area.

Previous to this, the sprays would have been checked and set for the desired pattern for the particular grade to be cast and the roller apron alined. The pinch rolls also would have been set to the desired size and pressure. The torches and lowering mechanism are set for the size and length of bar to be cut. The various controls have been checked to ensure proper operation.

At the furnace, the metal temperature is carefully checked and controlled prior to tapping. When ready, the heat is tapped into the ladle through an opening in the cover and the ladle is transported to the casting department.

On the casting floor, the ladle is set in the tilting cradle. An oil burner is positioned over a hole in the ladle cover and is used during casting to direct a high intensity flame onto the metal. By this means, temperature drop can be reduced to less than one degree per minute. A propane atmosphere is directed at the ladle spout, tundish and mold to protect the molten metal against oxidation.

The mold water is turned on, the ladle is tilted and metal begins pouring into the tundish, through the

tundish nozzle into the mold; metal level in the mold and speed of casting is controlled by close co-operation between the caster and the tilter.

As the billet leaves the mold, the spray water is turned on to complete the solidification begun in the mold. It is desirable to have solidification completed by the time the bar leaves the spray chamber so that spray water volume must be controlled accordingly. The spray pattern is also important—it must be such as to eliminate unequal strains and stresses which could warp or crack the bar.

When the dummy bar reaches the cutting chamber, it is removed and set aside for the next run. A small discard is made on the as-cast bar and then it is cut into the desired lengths and discharged.

The present stage of development of continuous casting at Atlas has been reached only after a great deal of effort and experimentation. Various "bugs" in the equipment had to be worked out first in order to ensure the continuity of a casting run. Many metallurgical and quality problems had to be solved before a billet of acceptable quality could be produced. The knowledge so far obtained has been collected the "hard way." Some of the problems which had to be overcome during the development of this process are as follows:

1. *Temperatures*—Temperature is a very important factor in continuous casting. Too high a casting temperature can result in a breakout below the mold due to remelting of the shell. An excessively high metal temperature can also contribute to a very poor surface. Too low a temperature will cause freezing in the nozzle and can produce an excessive amount of ladle skull. Optimum casting temperatures must be determined for each grade. Furnace tapping temperatures must then very carefully be determined and controlled to give the desired metal temperature at the casting floor. For heats which arrive at the casting floor too hot, a technique of argon injection has been developed to cool the metal to the desired temperature.

2. *Ladle problems*—The first requisite in a lip pouring ladle is a properly designed dam to hold back the slag as the ladle is being tilted. Several designs were tried until the present "S" dam was adopted which has proved very successful. In order to produce a good, clean stream of metal from the ladle into the tundish, a spout of proper size, shape, depth, slope and curvature is required. The solution to this problem was mainly one of trail and error. Ladle refractory erosion by the slag has been overcome by limiting the amount of slag in the ladle and by using magnesite brick in certain areas in place of regular ladle brick. Even such a relatively simple matter as ladle heating has required some study. We find that we can greatly minimize ladle skulls by a long ladle heating cycle, which thoroughly "soaks" the ladle brick. Any skull which does form is made easily removable by previously coating the ladle with a slurry of fireclay.

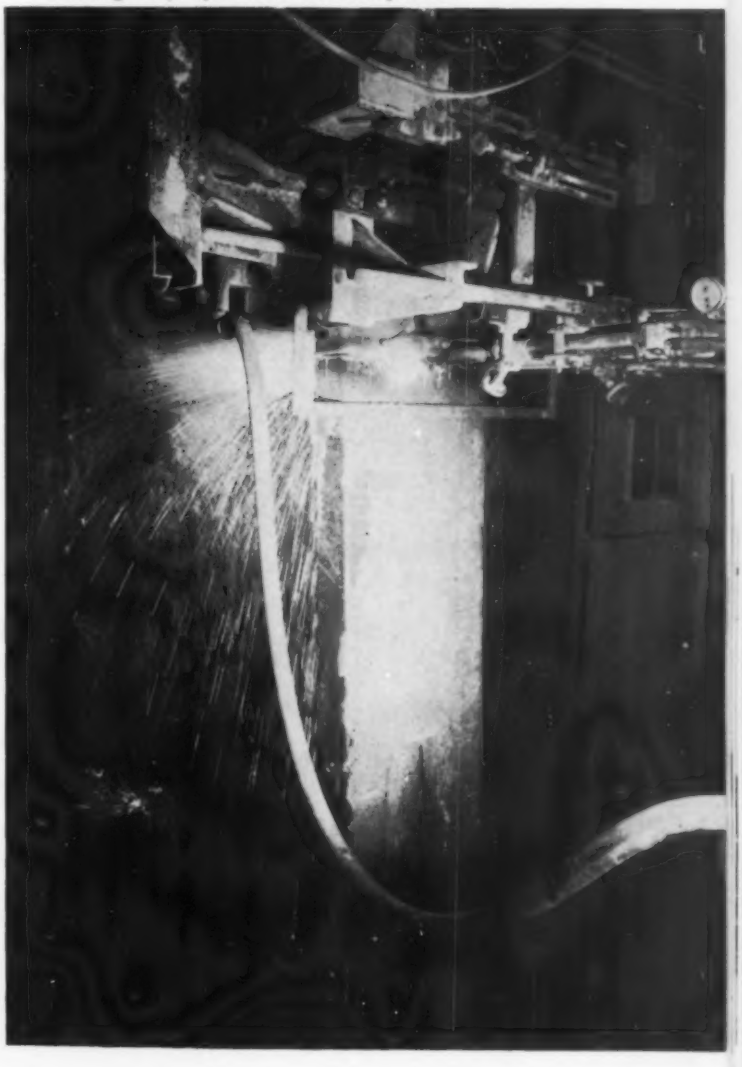
3. *Tundish problems*—The tundish presented problems in design of the slag baffle, control of metal level, quality of metal stream into the mold, heat retention and others. The present tundish nozzle design was adopted only after extensive testing.

4. *Mold lubrication*—To prevent sticking of metal to the walls of the mold, it is necessary to introduce a rapeseed oil into the mold. The original exterior oil lines have been replaced with drilled passages in the mold through which the oil flows. A variable speed drive on the lubricator provides control of the quantity of oil being introduced in the mold.

5. *Protective atmospheres*—A protective propane atmosphere is maintained about the exposed metal surfaces to prevent oxidation. Various means and methods of applying and maintaining this atmosphere have been devised to prevent oxidation and skulling in the spout, tundish, at the tundish nozzle and in the mold. It has also been found that insufficient propane in the mold allows the rapeseed oil to burn off causing a smoky atmosphere which makes it difficult for the machine operator to see the metal level in the mold. A proper protective atmosphere has eliminated the skulling troubles which were common in the beginning.

6. *Spray cooling*—The most important part of the process as regards to internal quality, is the spray cooling. A properly balanced spray pattern is necessary to produce a bar free of center cracks. This involves the cooling along the length of the bar, around its perimeter, actual area covered by the sprays, distance of the nozzles from the casting, total amount of spray

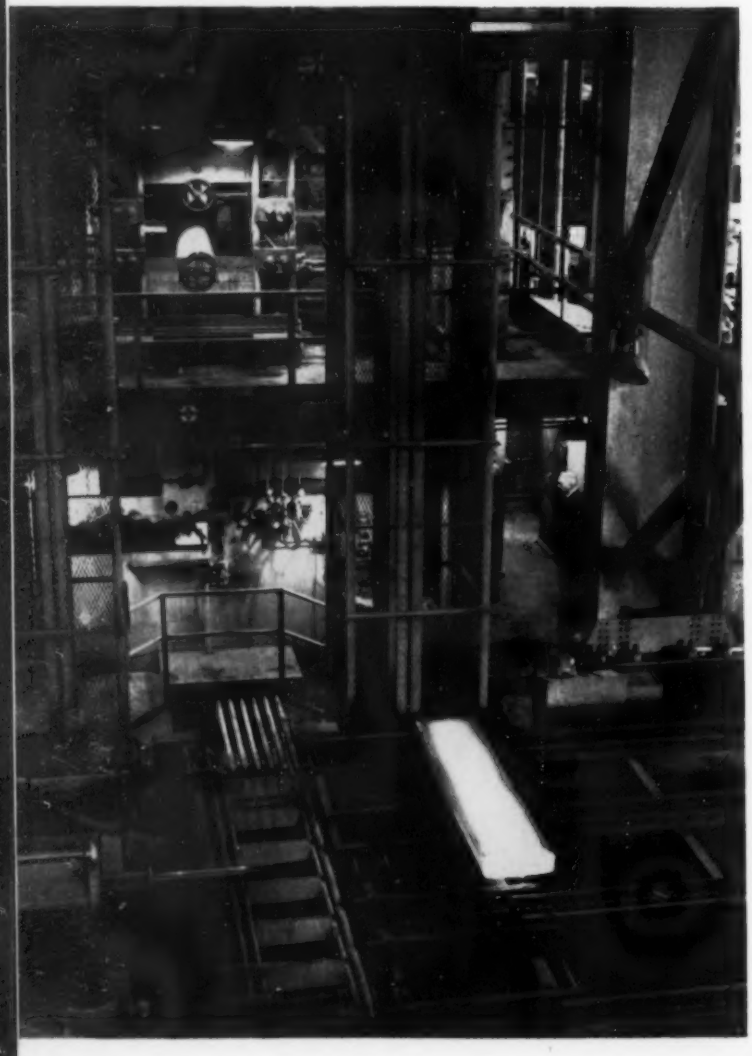
Figure 5 — A dual torch system is used for cutting castings. The twin torches move downward with the casting and cut it into desired lengths. They automatically clamp on the casting, and cut and release from the casting in proper time and sequence.



water used and other factors. Excessive cooling can be the cause of internal cracks but insufficient cooling on certain shapes can also cause internal cracks. This applies particularly to a rectangular section, where the edge is undercooled in relation to the face. Insufficient cooling can cause a bulge in the bar due to the thin shell being unable to withstand the ferrostatic pressure of the molten crater. Various weird phenomena can be caused by improper spray cooling.

7. *Mechanical handling*—The billet disposal equipment had its share of bugs. To complete the process, it is necessary to cut the billet into the desired lengths and dispose of it while the cast is in progress. The main problem here, has been to find a dependable means of cutting the bar. Oxyacetylene powder torches were decided upon originally, but considerable development was necessary to ensure their dependability in such things as powder flow, constant speed of torch travel, fast cutting, freedom from spitbacks and so on. Special post-mixed cutting nozzles had to be developed for this job of cutting. The mechanical handling equipment had to be revised and re-designed to eliminate the "bugs." Even such things as placement of control buttons required changes. On one occasion, an overly-exuberant crew member accidentally pushed the "stop" button during a cast while trying to be of assistance. Since then, the controls have been so placed and guarded as to prevent accidental operation.

Figure 6 — Finished slab has been deposited on table equipped with drag chain which slides the slab to a pickup cradle.



8. *Surface quality*—It has been necessary to learn the various factors which affected surface quality. Mold lubrication, propane atmosphere protection, metal temperature and speed of casting all have an influence on surface. A good surface is produced only when all these items are under proper control.

9. *Melting techniques*—In our melting, aluminum is often added to the steel for purposes of deoxidation, grain refinement and special properties. We have found that with our steels, aluminum contents in excess of 0.02 to 0.04 per cent (depending on grade), make it extremely difficult to cast. High aluminum invariably causes the tundish nozzle to skull up to such an extent that casting is impossible. In the case of tool steels, this problem has been overcome by using vanadium for grain refinement. For grades where aluminum is necessary, a method of adding aluminum in the mold during casting is being developed.

Hydrogen presents somewhat more of a problem in continuous casting than in conventional ingot pouring. Heats which produce acceptable quality in ingots may produce continuous cast billets with subsurface gas holes. Apparently, the hydrogen content of steel for continuous casting must be lower than for ingot casting to produce freedom from gas trouble.

Problems like these, together with necessity for more precise temperature and slag control, indicate that previous ideas and concepts must be changed when melting for continuous casting as compared with standard ingot pouring.

Some of the problems required only simple solutions while others required a great deal of time, effort and study to eliminate. The knowledge gained has been hard won. Although it can be said that continuous casting of steel is a success, its development is by no means complete. Efforts are continually being made to improve the process, to add more grades to the list which can be successfully cast and to further improve quality.

STEELS CAST AND METALLURGICAL ASPECTS

Grades cast to date include:

18-4-1 high speed.
Valve steel.
Alloy machinery steels.
Carbon tool steels.
Chrome-tungsten tool steels.
Stainless 300 and 400 series.

The tool and stainless steels can be cast with no particular trouble. Strangely enough, the machinery steels cause a greater problem than any other grade—particularly due to center cracks. On the other grades, good centers can be produced with only slight porosity in the as-cast section which welds up on rolling.

Cleanliness in general, is as good or better than in ingot material. Where control of grain size and hardenability is required, it is being successfully accomplished by the use of vanadium. Chemical segregation is not a problem, there being very little difference in analyses between the first and last of the cast.

A metallurgical research and development program has been set up to correlate the various factors required

to produce optimum quality and to expand the list of grades which can be successfully cast. Such a program will permit casting new grades with much more certainty of results and less problems than during the original development stages. The data thus collected, for example, can be used to establish the proper ranges of speed and cooling required for the production of sound billets and freedom from center troubles.

ADVANTAGES AND DISADVANTAGES

While there are certain advantages to be gained from continuous casting, there are also some disadvantages.

One of the main advantages is an improvement in yield of approximately 10 per cent over conventional ingot practice. This, of course, is due to the elimination of hot top and butt discard. Furthermore, there are no "butts," i. e. less than full ingots at the tail end of the heat which often occurs with regular ingot practice. In continuous casting, the cut lengths can be adjusted to the requirements of the order, eliminating "shorts" which frequently occur when cogging ingots.

In addition to these savings, the use of continuous casting can eliminate or reduce subsequent operations. For example: a 5½ x 21½ in. continuous cast slab can be reduced to 2¼ x 19 in. size for the strip mill in 13 passes on the bloomer. Using a 22 in. ingot, a total of 32 passes is required. Furthermore, depending on the individual conditions, blooming mill and soaking pit installations could be eliminated completely with a considerable reduction in capital investment.

The very fact that the process is continuous is one disadvantage in that it must remain continuous for the full period of the cast. If trouble of a major nature occurs, such as a cutting failure or nozzle freeze-up, the process cannot be interrupted temporarily and then resumed. What is left in the ladle is either scrapped or if possible, poured into ingots. The continuity of the process depends on careful attention to details to ensure that each phase of the operation will function properly.

The size of casting is at present limited due primarily to a lack of suitable means of cutting a large section. This will quickly disappear in the case of the slab, if the anticipated method of pierce cutting is successful.

Scheduling of the melt shop so that heats will tap in proper sequence is a problem. The fact that heats would have to be properly spaced could result in furnace delays or lost production on the machine.

Another factor of concern to the melt shop is the drop in returned mill scrap due to higher yields on continuous cast material. This mill scrap is usually depended upon as a source of good melting scrap.

However, it is felt that the savings inherent in continuous casting, certainly outweigh the disadvantages.

NEW DEVELOPMENTS

The present stage of development of the Atlas machine is by no means the ultimate. Further progress is continually being made.

Automatic controls for ladle tilting and mold level control have been developed which can correlate the rate of metal flow from the ladle with the machine speed.

The original molds used for casting were 20 in. long. At present, we are operating with one mold which is only 10 in. long. This has proven successful and as new molds are ordered, they will be 10 to 12 in. long rather than the "long" 20-in. mold.

Work is being done currently on measurement of molten crater width and depth in an effort to increase the present knowledge of the method of solidification during continuous casting.

A method of adding aluminum in the mold during casting is being developed for use on grades where aluminum is required.

To reduce slab handling after casting and expedite heating and rolling, a high head continuous slab heating furnace will eventually be placed in line with the concast billet discharge conveyor and the blooming mill.

At present, a 2½ x 17-in. mold which will supply slabs directly to the strip mill is being prepared and will soon be tried.

The development of the continuous casting of steel has, by no means, reached its ultimate stage. As more work is done on the Atlas machine, and on other machines in the future, the art and science of continuous casting will be further perfected to the stage where it will be a standard method of production in many steel plants.

It has been proven at Atlas that continuous casting is commercially successful. This machine is only the first of many and larger installations which will soon make their appearance in the steel industry.

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Cause and Prevention of Hot Strip Work Roll Banding

By CHARLES E. PETERSON

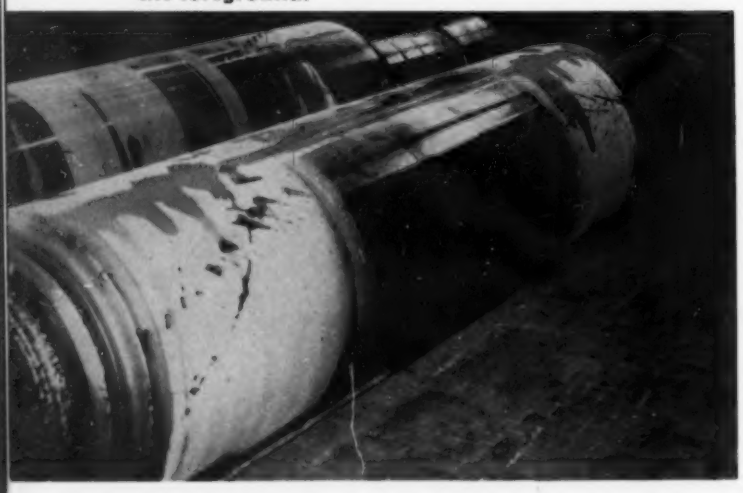
Chief Metallurgist, Mackintosh-Hemphill Division, E. W. Bliss Co., Pittsburgh, Pa.

▲ BANDING on work rolls is a serious problem in 4-high hot strip mills. It is true that the battle to overcome this banding has been won by some mills, but it is also true that a slackening of effort in those mills would allow the trouble to recur. This paper is an attempt to summarize opinion as to the cause and means of overcoming the banding problem, with particular emphasis on the rolls themselves.

Before proceeding further, it would be wise to define the term "banding." Banding, which occurs primarily on the rolls of the first two finishing stands, is caused by the adhesion of sizeable patches of scale on the roll surface. Generally the scale patches are elongated in the direction of rolling, giving the appearance of bands, and thus giving rise to the term "banding." These scale patches, which have a finite thickness, make an impression upon the surface of the strip, creating an uneven gage. In addition, portions of the scale patches are sometimes removed from the roll and become imbedded in the strip.

The scale originates primarily from the strip, since oxidization occurs very readily at rolling temperatures. The scaling of the roll itself is, although probably present, negligible as compared to the scaling of the strip.

Figure 1 — View shows typical banded rolls. One in rear illustrates a worse banded condition than the one in the foreground.



The first step in overcoming the banding problem is to remove the scale from the strip prior to contact with the rolls of the finishing stand.

The large amounts of scale which are formed in the heating furnace are generally removed by a stand of scale breaker rolls ahead of the roughing train. However, the strip is exposed to oxidizing conditions for an appreciable time after passage through the first scalebreaker, and before entering the finishing train. During this interval, a secondary scale is formed.

It has been noticed that mills with extra long runout tables have a much more brittle secondary scale formation than do mills with short runout tables. This is undoubtedly due to the cooling of the strip surface while crossing the table. This is an important fact, since most mills are equipped with a second scalebreaker stand immediately ahead of the finishing train. This stand performs almost no work on the strip, but simply kneads the surface of the strip, breaking loose the scale. Such mechanical action is much more effective on cold brittle scale than it is on hot, ductile scale. In addition to the second scale breaker, it is generally necessary to spray the strip with high pressure water jets in order first, to embrittle the scale by cooling, and, second, to blast it from the surface.

Unfortunately, all of the scale is seldom removed, and some of the loosened scale is carried by the moving strip into the finishing train. In addition, since the strip is still red hot, further scale continues to form, even while the strip is passing through the rolls. This newly formed secondary scale and the scale remnants cause the banding problem.

Certain types of rolls have been found by experience to provide greater freedom from banding difficulties than other types of rolls, all other conditions being equal.

. . . . one possible solution to the banding problem is to carry out three practices . . . . first, remove all scale from strip as well as possible before entering finishing stands . . . . second, select a roll material combining high hardness with freedom from graphite . . . . third, apply large quantities of water at elevated pressures to keep the rolls as cold as possible . . . .

In the early days of the strip mill, most intermediate and finishing rolls were made of plain chilled iron or nickel chill iron. At that time production rates were rather low and banding was not a problem in most mills. The attainment of greater production rates proved rather conclusively that chill type rolls had a tendency both to break and to spall, because of which nickel grain rolls were developed and applied in these stands. These rolls did not break or spall but unfortunately, banding became a problem, and rather frequent roll changes became necessary.

Shortly after the nickel grain roll was developed, double pour high nickel iron rolls were developed for use in the finishing stands. In some mills the partially worn finishing rolls were "used up" or worn out in the intermediate stands. Usually, these rolls provided better service than did the low nickel grain rolls.

The use of both new low nickel grain rolls and partially worn double pour rolls in the stands was predicated on two assumptions. These were: (1) high hardness was not necessary for the production of good strip surface, and (2) high hardness led to slippage and roll breakage.

In more recent years, both of the previous assumptions have been repudiated by a successful series of experiments. These experiments started with the development, by the roll makers, of heat treatments which could satisfactorily lower the hardness of high nickel double pour rolls. These rolls when heat treated to hardness levels of 72/76 scleroscope, provided an appreciable freedom from banding, accompanied by higher roll tonnages, particularly when used in the troublesome stands as new rolls.

This series of developments has made it possible to determine, in retrospect, some of the factors which influence banding in work rolls. Clear chill type rolls, although not tough enough to withstand the service, did not develop banding. New, high nickel double pour rolls did the next best job, followed in relative order by low diameter double pour rolls and then by low nickel grain rolls.

When a study is made of the microstructure of these rolls, it is found that, in general, the graphite content of the rolls is in the same relative relationship as the freedom from banding. Chill rolls, of course, have no graphite in the chilled surface layer, regardless of depth. Due to the high alloy content of the shell material, the graphite content of double pour rolls is quite low near the as-cast surface, but the graphite increases in both size of flake and number of flakes as the roll is reduced in diameter. The low nickel grain roll, since it is not generally double poured, must be made from a relatively graphitic composition in order to avoid the occurrence of brittle white iron fracture.

Roll makers have found from experience that graphite at the roll surface does two things in a hot strip mill work roll. First, it contributes to firecracking, and second, the graphite flakes "pull out" of the roll surface. These two mechanisms have one thing in common. Both provide or create small fissures in the roll surface. These fissures are excellent locations into which scale can be forced by rolling pressure, mechanically locking it into place on the roll surface. These small particles of scale then tend to weld to still more scale, until sizeable patches are formed.

The most recent development insofar as rolls are concerned is the use of 1.20 to 1.40 per cent carbon alloy steel rolls in the intermediate stands. These steel rolls are similar to clear chill rolls in that they contain no graphite. However, they possess the strength which clear chill rolls do not have to resist breakage and spalling. The composition is such that, when combined with proper heat treatment, fire cracking is negligible. Accordingly, very little mechanical locking of scale to the roll surface is possible.

In addition, steel has a greater co-efficient of thermal expansion than does iron, which plays an important part in the removal of scale from the roll surface. The alternate heating and cooling of an iron roll is not accompanied by much flexing of the roll surface. Steel rolls, however, flex an appreciable amount, thereby tending to break off the scale in much the same manner as ice is removed by the rubber de-icing boots on airplane wings.

One problem which has been evident in steel rolls has been the result of the lower hardness of these rolls, which leads to tail marking. It has become imperative in most mills that steel rolls be hardened to at least 50 scleroscope. Because of the beneficial aspects of greater hardness, the use of nickel in steel rolls has been indicated to be of some value. Nickel chrome moly rolls may be tempered at a higher temperature than many chrome moly rolls. This means that the tempering action of the hot strip is less effective on the nickel rolls, thus maintaining a higher roll hardness and, consequently, less trouble due to tail marking.

As mentioned before, greater production rates have yielded some insight into the mechanism of banding by correlation with the types of rolls which have been used. There is another correlation which can be made—this having to do with the roll temperature. The greater the production rate on a given mill, the more difficult

it becomes to cool the rolls. Also, since the slab is generally processed through the mill with greater speed, the actual strip temperature in any given stand is generally higher. This high temperature of both the strip and the roll yields a thin, viscous, sticky scale which will adhere to the roll surface more readily than will a brittle, cold scale. In addition, the higher the temperature, the easier it is for the graphite in the roll surface to be picked out. Both of these factors will quite apparently increase the amount of banding which is noticed.

It thus becomes apparent that the application of water to the rolls for cooling is a very important function with regard to the elimination of banding. Several theories with regard to roll cooling have been advanced. One theory holds that rolls can best be cooled with extremely large volumes of water, without much regard for water pressure. This theory is held to be somewhat in error, since the temperature of the roll surface is above the boiling point of the water, and an insulating barrier of steam is formed. Such a steam barrier nullifies the cooling power of the major portion of the water. The second theory holds that high pressure water, is the best method of roll cooling, since the water pellets, due to their high velocity, will effectively penetrate the steam barrier, thereby coming in contact with the roll to perform the cooling function. The high pressure water penetrates the steam barrier because of its velocity but, unfortunately, it also rebounds from the roll with equal velocity thus permitting only a short contact time between water droplets and roll surface. This short contact time does not allow for adequate cooling.

The best water applications seem to be those in which a combination of the two above theories are used. There are several types of combinations possible. some of which are as follows: Some mills use a small volume of high pressure water (approximately 1000 psi) in conjunction with a large volume of low pressure water (40-60 psi). The high pressure water will break up the steam barrier, allowing the large volume of low pressure water to come into contact with the roll, insuring adequate cooling. The second water application which seems to be effective is to apply a large volume of water to the roll at an intermediate pressure (perhaps 200 psi), just sufficient to break through the steam barrier, but not so high as to cause the water to splash rapidly away from the roll.

Unfortunately, some mills do not even have a large supply of cold water. Mills located on small inland streams often find that their incoming water is 100 F or hotter, particularly in the summer time. On the other hand, mills located on large lakes have a plenteous supply of cold water at all times. In either case, the space necessary and the cost of the pumps is often a problem which must be solved before the necessary volumes of high pressure water may be provided.

All of these variables lead to the natural result that cooling water is applied in a different manner in practically every strip mill, based for the most part on the economics of that given situation.

The prevention of banding on the work rolls of the intermediate stands of hot strip mills is derived from economic necessity. Down time for roll change is probably the most important single factor in determining the production capacity of a given mill. Likewise, economics must be considered with regard to descaling equipment, type of rolls to be purchased, and method of roll cooling. The most expensive of the roll types mentioned is the steel roll; the least expensive is the low nickel grain roll. Best roll tonnage is obtained from double pour high nickel grain rolls, providing that water is supplied in such a manner as to maintain a low roll temperature. However, many mills have found that either the cost, or the availability, of cooling water and pumps more than offsets the expense of the high priced rolls.

Since it would not be possible for any one paper to set forth a practical solution to the banding problem in all strip mills, the best possible summary for this paper can be made by setting forth three rules:

1. Wash off, break loose, and in any other manner possible, remove all scale from the strip prior to entry into the finishing stands.
2. Select a roll material which provides the best combination of freedom from graphite and high hardness.
3. Keep the work rolls as cold as is possible by judicious application of water in large quantity, and at an elevated pressure.

DISCUSSION

PRESENTED BY

W. C. KOSTBADE, Superintendent, 76-in. and 44-in. Hot Strip and No. 3 Blooming Mills, Inland Steel Co., East Chicago, Ind.

CHARLES E. PETERSON, Chief Metallurgist, Mackintosh-Hemphill Div., E. W. Bliss Co., Pittsburgh, Pa.

E. O. REESE, Superintendent — Hot Strip Mill, Youngstown Sheet and Tube Co., Youngstown, Ohio

G. W. RANSOM, General Foreman, Roll Department, Republic Steel Corp., Youngstown, Ohio

W. C. Kostbade: Has Mr. Peterson had any experience with the effects of intermittent rolling, that is, rolling at an un-uniform rate?

We have found at Inland that if a set of rolls has been brought up to proper rolling temperature at a slow rolling rate, it will last a long time without banding. On the other hand, if a high rate of production is resumed after a delay, the rolls band rather rapidly.

Have actual experiments or tests been made to substantiate the statement that mill scale is picked up by the rolls and in some cases deposited on the band being rolled?

We do not feel that this occurrence has ever caused us any trouble.

We find that when a "banded" roll is ground, the "banded" area always proves to be the area of the smallest diameter in the roll body. We, therefore, feel that this area is not built up but is actually cut down.

If the tail end of the strip entering finishing train is

cropped off squarely and the strip is rolled on banded rolls, we find an indentation on the normal contour of the tail end.

The theory of banding being started from a graphite pit on grain rolls is true, but it is also true that banding will result or develop from any depression in the roll or from a very minor spall or chip out of the roll.

Have you found, in any of the studies made, any method of water application which has proven to be more efficient than another? Do you think the flat spray is more efficient than water from a drilled hole?

Reference is made to some mills using a small volume of 1000 psi water with a large volume of low pressure water for roll cooling. We are curious as to the maintenance problems of applying this high pressure to work rolls.

Charles E. Peterson: I will take these points one at a time. First, you asked whether I had any experience with the effects of intermittent rolling or other interruptions. The simple answer to that is "No." I have no experience whatsoever with that point.

So far as actual tests are concerned, we have made none to prove that scale is picked up by the strip. I have seen strip which contained some rolled in scale. It is my belief that at least some of this scale came from banding which came off the roll surface. But that has yet to be proven, however. We do know quite definitely that the scale on the rolls is picked up primarily from the strip. When a sample of the banded roll is polished through the band, it is quite apparent that the scale is of a foreign nature rather than scale from the roll itself. The appearance under the microscope is different.

You remarked that the banded area appears to be smaller in diameter. I think I should perhaps ask a question here: Were those rolls measured hot or cold?

It is my opinion that if the rolls were calipered cold the banded area would be a high diameter point.

W. C. Kostbade: When a banded roll is placed in roll grinder, you have to take two or three passes before the banded area is polished off.

Charles E. Peterson: From our observation of rolls that have to come back as scrap, it has been my feeling that these banded points were high. If that is not the case then we can infer that the band occured at some point where the temperature was non-uniform with respect to roll material immediately adjacent to the band, so the scale could adhere more readily at one spot than another. This could be due to non-uniform application of water perhaps. That sounds very logical to me.

W. C. Kostbade: Where you have a non-uniform application of water, that will show on the surface.

Charles E. Peterson: You also ask whether we have found through study whether there is any one method of water application which is better than another.

We have not made too full a study of it, but in general, any application which distributes the water uniformly over the entire surface is better than an application which does not distribute it uniformly. On that basis a flat spray would be preferable to any other spray.

You also asked about the method of cooling, wherein a small amount of high-pressure water is combined with a large amount of low pressure water. You want to know about the maintenance problem. I cannot answer that question.

E. O. Reese: In my opinion Mr. Peterson has shown that he has a thorough understanding of the operation and problems involved in attempting to produce a hot rolled strip with the proper type of surface. On our 79-in. hot mill at Youngstown we have used practically all the types of rolls discussed in this paper and our experience agrees almost exactly with Mr. Peterson's statements as to the amount of banding on the types of rolls discussed. At present we are using practically all steel rolls in 5, 6, and 7 stands and we have practically no trouble with banding.

I would like to ask Mr. Peterson's opinion on the minimum water pressure that should be used on No. 2 scalebreaker for proper descaling and also his opinion of our practice of using one-half the normal crown on the steel rolls.

Charles E. Peterson: I should think that scale breaking water pressure would have to be determined by conditions in a given mill. The type and the amount of scale which must be removed by the high pressure water will vary from mill to mill, depending on the length of the table, type of steel, and a number of other factors that enter into the picture. Therefore, it is very difficult for me to say anything with regard to the minimum water pressure necessary.

Regarding the amount of crown on steel rolls, I agree very definitely with your practice of using less crown on the rolls. The expansion of steel is appreciably greater than that of iron. It is often necessary to dress the steel rolls concave in order to obtain a uniform pressure across the width of the strip. This is now only necessary from the standpoint of uniform gage, but also from the standpoint of the effect the uniform pressure and uniform heat transfer across the width of the strip have on banding.

G. W. Ransom: It is my opinion that the author has very ably summarized the causes of hot strip work roll banding and the ways of preventing this troublesome factor in hot strip mills. I can confirm most of his opininons by our experience in our strip mills at Youngstown, Warren and Cleveland. I have heard that there has been some experimentation with the use of emulsified oil applied to the work and backup rolls in these stands to eliminate banding, and was wondering if the author has heard anything about this, if so would like to hear more about it.

Charles E. Peterson: I have heard nothing about the last mentioned practice.

The subject of banding is both interesting and vital to all strip mill operators as well as to roll makers. It was my firm wish, at the time I began writing this paper, that some good, enlightening discussion would be aroused. Questions have arisen in the course of this discussion which are as yet unanswered. In fact it seems quite possible that some disagreement exists as to the definition of the term "banding." Now that such a discussion has arisen, it is hoped that it can be continued until the problem is thoroughly understood and solved.

By J. E. PEEBLES, Steel Mill Engineer, Systems Application Engineering Section, General Electric Co., Schenectady, N. Y.

Power Requirements and Selection of Electrical Equipment for reversing cold strip mills

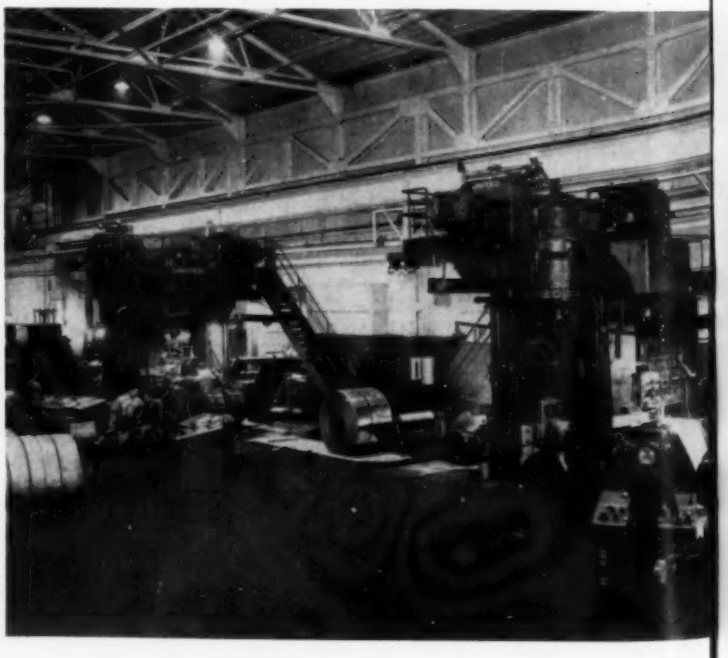
. . . . for the best design of a reversing cold strip mill, the machinery manufacturer, the electrical manufacturer, and the user must coordinate their requirements to arrive at a common solution for their problems . . . . it is essential that the purchaser of the mill understand the fundamentals of selecting the motors, the generators, and the control systems to make sure that the recommendations for the proposed design suits his own particular requirements . . . .

▲ THE most versatile of all of the mills for the cold reduction of metal strip is the reversing cold strip mill. Ability to make any desired number of passes with the amount of reduction adjustable with each pass, and the provision for accurate control of both front and back tensions combine to enable the operator of a reversing cold strip mill to roll a wide variety of materials with comparative ease.

The reversing cold strip mill consists of a roll stand, identical left and right reels, and screwdown and other auxiliary equipment. The initial pass may be from a coil box or from a payoff reel. This initial pass is sometimes made through a flattener or a leveler when the strip is heavy and needs straightening before entering the mill. Back tension on the first pass may be obtained by a drag generator on the payoff reel or by friction from blocks at the entry guides of the mill. Friction drag at either the reel or leveler or both is also used occasionally.

Reversing cold strip mills fall into two classes, 4-high and cluster mills. These can be driven mills or pull-through mills. The driven 4-high mill is the most common and is usually considered as the general duty mill of its type (Figures 1 and 2). It has two work rolls and two backup rolls lined up vertically in a housing similar to that of a tandem cold strip mill. Either the work rolls or the backup rolls may be driven. It has two driven reels, the unwinding reel providing drag tension and the winding reel providing winding tension. The delivery speed of the mill is set approximately by the work roll surface speed since the effect of extrusion is small except for those mills which roll the softer metals. For mills rolling brass or aluminum, a delivery speed in excess of the work roll surface speed may be obtained due to the more pronounced effect of extrusion. This effect is especially noticeable on aluminum rolling mills.

Figure 1 — These two 16½ and 53 x 48-in. reversing strip mills each have two control desks.



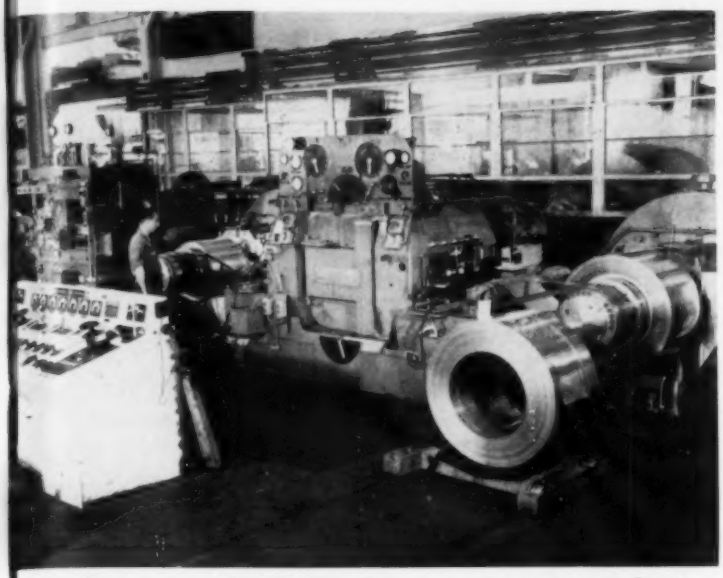


Figure 2 — View shows 15-in. reversing cold strip mill at the Wallingford Steel Co. with payoff reel, flattener and tension device, left reel, mill, electrolimit and beta ray gages, billy roll with pilot generator, right reel. Drive motors are behind glass in background.

A cluster mill is similar to a 4-high mill except that the work rolls are backed up by a cluster of backup rolls and possibly backup bearings designed to give horizontal support as well as rigid vertical support to the work rolls. The most common of the cluster mills in operation in this country is the sendzimir reversing cold strip mill (Figure 2).

The pull through mill can be considered a special case of the reversing cold strip mill. It consists of a main roll stand which is not driven and two reels of which only the winding reel is driven. The drag on the unwinding reel will be obtained by frictional means. When a reversal of the mill occurs, the driving motor coupling is shifted from one reel to the other reel. In general the following discussion will cover electric systems for driven mills. However, additional comments will be made covering pull through mills where these comments are applicable.

MILL STAND AND REEL DRIVE REQUIREMENTS

The type of electric drive most suitable for use with any mechanical equipment is determined by the operating requirements. The reversing cold mill is called upon to make many passes at many different speeds. The speed of any given pass depends upon many things including the type, quality, thickness, and hardness of the material. The early passes on most products are the heavy reduction passes since they are made when the strip is thick and comparatively soft. These passes require high torques and low speeds in general. On the other hand the plater passes in the rolling of the same strip are made when the material is comparatively thin and hard. These passes are usually best made near top speed but with light torque requirements.

It is also desirable that the speed of a reversing cold strip mill remain constant throughout a given pass. Among the elements which may cause errors in gage are changes in mill speed and changes in winding or unwinding tension unless other compensating changes are made. A constant mill speed is desirable from the tension standpoint, since it will make the job of the reels in holding constant tension easier by eliminating the effects of inertia during change of speed. The desirability of constant mill speed to keep gage constant is an important consideration in the selection of a driving motor.

Another factor in the choice of a driving motor is the type of acceleration and deceleration required. In order to hold constant tension from rest to running speed the winding reel motor must produce additional torque over the torque required for tension. This additional torque is necessary to compensate for the effects of inertia. During deceleration, the torque of the winding reel must be reduced because of inertia. Similar changes in torque are necessary during acceleration and deceleration for the unwinding reel. If this inertia compensation, or forcing, is not provided, variations in

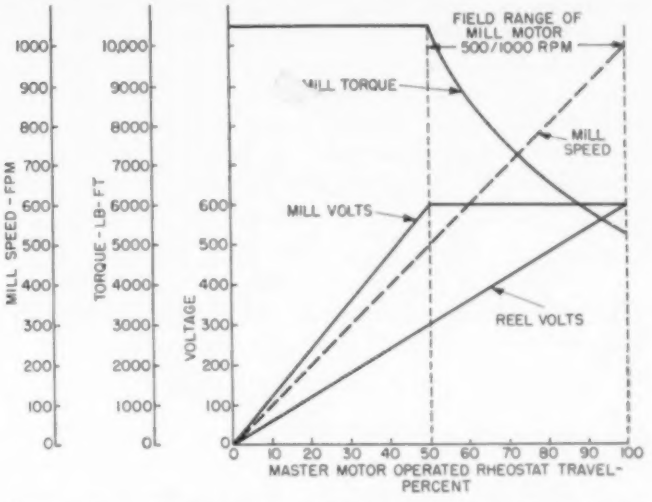


Figure 3 — Mill speed, mill torque, and mill and reel voltage are given vs travel of motor operated rheostat. Mill motor is 1000-hp, 500/1000-rpm, 600-volt.

gage due to tension changes can be expected during acceleration and deceleration. Extreme variations of tension would cause either looping or breaking of the strip. A uniform acceleration and deceleration enables accurate and efficient inertia compensation to be programmed by the electrical equipment. Inertia compensation can be obtained from an indication of rate-of-change of speed, but in the past programmed inertia compensation to a predetermined accelerating and decelerating rate has been most common.

MILL STAND

A d-c shunt wound motor with its speed adjustable by both voltage and field best fits the requirements for the mill stand drive. The curve of Figure 3 shows how the speed of such a mill motor is adjusted from zero to top speed of the mill. It can be seen that the voltage of the motor is increased until the motor reaches base speed after which the field is weakened until the motor reaches top speed.

This sequence can be programmed by a motor operated rheostat and produces constant torque to base speed of the motor and constant horsepower, with diminishing torque, throughout the field range from base

to top speed. Such a motor characteristic will produce high torques for the low speed passes and progressively lower torques for the high speed passes.

REEL

A d-c shunt wound motor adjustable in speed by both voltage and field likewise fits the requirements for the reel drive. The reel motor is required to hold constant tension under all operating conditions. Constant tension from zero to top mill speed means the horsepower must be proportional to mill speed. Also constant tension at constant running speed means constant horsepower. Both of these statements can be demonstrated by the fomula:

$$\frac{\text{Tension} \times \text{fpm}}{33{,}000} = \text{hp (Neglecting losses)}$$

During a pass the coil diameters vary as material builds up on the winding reel and as the unwinding reel delivers material. Since this changes the lever arm at which the tension is applied to the motor shaft, the motor torque must vary proportionately to coil diameter. The following formula shows this torque requirement to be compatible with the constant horsepower requirement if torque is made to vary inversely with motor rpm.

$$\text{Torque} = \frac{5250 \text{ hp}}{\text{rpm}}$$

D-c motor characteristics are shown by the following equations:

$$\text{Torque} = K_T \phi \text{ I}, \quad E = K_E \phi \text{ Rpm}$$

ϕ = field flux

K_T, K_E = constants

I = Armature amperes

E = Motor cemf

These equations were used in plotting Figure 4.

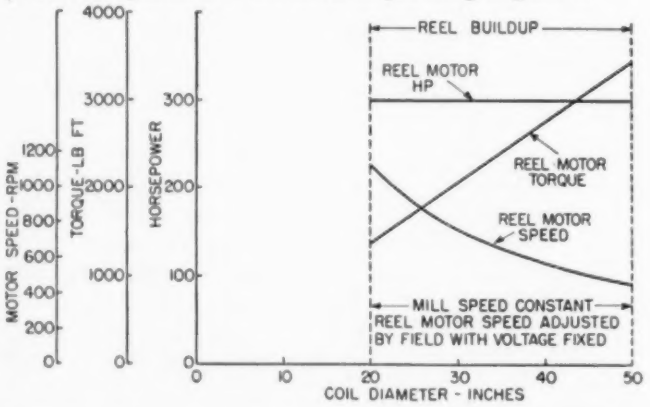


Figure 4 — Reel motor speed, torque and horsepower are given vs coil diameter over 20 to 50-in. buildup. Reel motor is 300-hp 400/1200-rpm 600-volt.

Figure 4 shows hp, torque, and speed plotted against reel buildup with armature amperes and applied voltage held constant and with the motor field adjusted to correspond to changes in buildup. If reel motor voltage is changed in proportion to mill speed changes (See Figure 3) and if tension adjustments are made by changing armature amperes, all of the requirements of a reel drive are met in a d-c motor.

Occasionally a reel drive is encountered where it is necessary to provide full tension only at reduced speeds and light tension is acceptable at maximum speed. This requires adjustment of reel motor field for a change in mill speed. Such a range of field adjustment must be multiplied by the range necessary to cover buildup of the reel to select the rated speed range of the motor. The maximum speed range obtainable in a well designed motor limits the amount of reel motor field range which can be used for strip speed changes.

SELECTION OF HORSEPOWER

Reversing cold strip mills are driven by heavy duty motors. The actual horsepower and speed range are generally specified by the mill builder. The mill builder can make this selection with an intimate knowledge

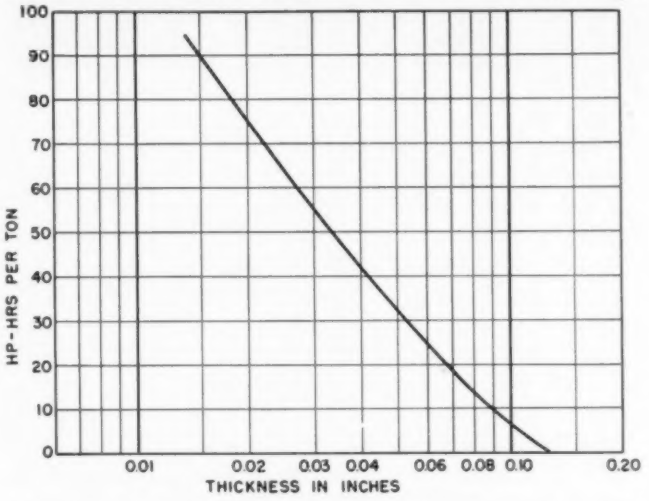


Figure 5 — Power curve covers cold rolling low carbon steel from 0.125 to 0.015 in. thick.

of the mechanical equipment, a wide experience with other mills of the same type, and calculations of power requirements from rolling schedules.

To calculate the horsepower required for the mill and reel motors, the principal rolling schedules for the mill must be determined. These rolling schedules will give the type of material, the number of passes to be made, the strip dimensions entering and leaving the mill for each pass, and the speed of each pass.

Knowing the rolling schedule and having selected the proper power curve, similar to that shown in Figure 5, the total horsepower required to make the desired reduction in strip thickness can be calculated. The power curve will give hp-hr per ton to make a given reduction in the strip. The power curve chosen should have been taken with rolling conditions, mill constants, and characteristics of the material rolled the same as or very similar to the material and conditions being considered.

The tons per hour are calculated from the strip dimensions and speed. The total rolling horsepower becomes a simple multiplication of hp-hr per ton and tons per hour. Several rolling schedules should be checked in order to determine which rolling schedule requires the most horsepower. If one particular schedule determines the maximum horsepower necessary and seems considerably out of line with the other, it may be desirable to revise this particular schedule.

TABLE I

Power Calculations

1. Pass	0	1	2	3	4	5	6
2. Thickness, in.	0.125	0.100	0.066	0.040	0.025	0.017	0.015
3. Per cent reduction	.....	20.0	34.0	39.4	37.5	32.0	11.8
4. Hp-hr per ton (total)	.....	6.4	21.0	41.8	63.7	83.0	89.6
5. Hp-hr per ton (net)	.....	6.4	14.6	20.8	21.9	19.3	6.6
6. Fpm out of mill	.....	500	500	600	900	1,000	1,000
7. Fpm into mill	.....	400	330	364	562	680	882
8. Tons per hr	.....	122.0	80.9	58.8	55.2	41.7	36.8
9. Rolling hp	.....	780	1,180	1,220	1,210	800	240
10. Tension winding reel, psi	.....	4,500	6,500	11,000	18,000	24,000	25,000
11. Tension winding reel, lb	.....	10,800	10,300	10,600	10,800	9,800	9,000
12. Hp winding reel	.....	164	156	193	295	294	272
13. Hp winding reel motor, actual	.....	175	167	206	316	314	291
14. Hp winding reel motor, rated	.....	350	334	346	350	314	291
15. Tension unwinding reel, psi	.....	.....	5,000	8,000	13,000	19,000	26,000
16. Tension unwinding reel, lb	.....	.....	12,000	12,600	12,500	11,400	10,700
17. Hp unwinding reel	.....	.....	120	138	213	235	286
18. Hp unwinding reel motor, actual	.....	.....	114	129	199	220	267
19. Hp unwinding reel motor, rated	.....	.....	345	354	354	323	302
20. Hp mill	.....	616	1,144	1,165	1,128	741	254
21. Hp mill motor	.....	635	1,180	1,200	1,160	765	262

Mill — 9½/10½ in. work roll, 1000 fpm maximum, material is 1010 steel, 24 in. wide, 20/45 in. diam, coil reduces from 0.125 to 0.015 in 6 passes as shown.

Having determined the total rolling horsepower, it is then necessary to divide this horsepower between the mill and the reels. The total rolling horsepower will be the sum of the horsepowers at the mill stand and the winding reel minus the horsepower removed at the unwinding reel. To determine reel horsepower, it will be necessary to select winding and unwinding tensions for every pass. These selections will be based upon plant practices, the type of mill, and the type of material. Tension can relieve screw pressure and help to maintain proper gage. It can also cause troubles such as roll chatter and strip breakage if not selected properly.

Once the tension has been selected, a simple calculation will determine the required horsepower at the reel block. Tension and speed are substituted into the following formula:

$$\text{hp} = \frac{\text{Tension} \times \text{fpm}}{33{,}000}$$

If the maximum tension from all schedules and top strip speed in fpm are substituted into this formula, the horsepower rating of the reel motor is obtained, neglecting friction. The winding reel horsepower should be divided by the drive efficiency and the unwinding reel horsepower multiplied by drive efficiency to correct for friction losses in the gears and other mechanical parts.

When making horsepower calculations for a reduced speed pass of a rolling schedule, as in Table I, it is necessary to use the reduced strip speed of the pass in the above horsepower equation. The horsepower so calculated will be the contribution, either positive or negative, to the total mill rolling horsepower by the reel in question. The rating of the reel motor necessary for such a reduced speed pass can be checked by using top strip speed in place of the reduced speed in the horsepower formula. The rating is then corrected for drive friction as described above.

The mill horsepower can be obtained by subtracting the calculated horsepower at the winding reel (line 12, Table I) from the total rolling horsepower (line 9, Table I) and adding the calculated horsepower at the unwinding reel (line 17, Table I) to the difference. Then divide by the stand efficiency to get the required main stand motor horsepower rating. Reducing strip speed below that corresponding to the stand motor's base speed does not enable the motor to do more work since the maximum motor torque is produced at base speed (Figure 3). Therefore, horsepower calculations will be made at base speed or above.

On the basis of the calculation in Table I, a 1000-hp mill motor and a 350-hp reel motor would be chosen. A 2 to 1 speed range is indicated for the mill motor since no pass requires more than the 2-hr overload rating (1250 hp) of a 1000-hp mill type motor and the schedule speed range is 500/1000 fpm. A 500/1000-rpm motor can be tentatively selected at this point.

Figures 6 and 7 show mill and reel hp per in. of width plotted against mill speed for a group of installed mills. The plots are divided roughly by type of material rolled and may be helpful for a quick comparison of a proposed mill with existing installations.

MILL STAND MOTOR RATING

An important part of the rating of a mill motor is its temperature rise. The normal motor will be rated with a temperature rise of 40 C, either open or forced ventilated. A forced ventilated rating, of course, is valid only when the machine is furnished with covers and an external air supply. The forced ventilated rating will generally be used on this class of mills since it may allow the designer to build the motor in a smaller diameter to obtain a lower WK^2. In any case, forced ventilation is always required if the motor is to run below base speed without overheating. Such ventilation also helps to keep the motor clean.

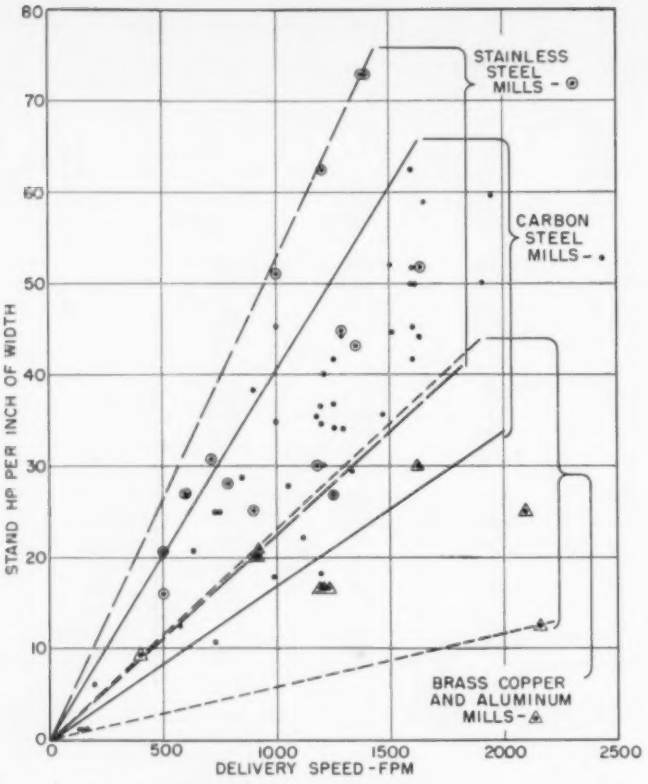


Figure 6 — Curves show mill stand hp per in. of width vs mill speed for a group of installed mills, and show a rough division by type of material rolled.

Another important part of the selection of the mill motor is its overload and commutating ability. The motor will almost always have 125 per cent load ability for two hours without exceeding a 55 C rise. This rating is based on the heating or steady state load on the mill. In addition to the 2-hr overload rating, the motor will be given a short time rating to indicate its commutating ability. This rating will normally be 200 per cent load for one minute, occasionally applied at base speed. These commutating limits will be reduced proportionately as top speed is approached. Some of the smaller mills which can be classified as medium duty mills have been furnished with motors (200 hp and less) of a standard industrial rating. These motors do not have a 2-hr overload rating and have commutating ability of only 150 per cent load. Mills which can be classed as either large or heavy duty mills should have the full overload and commutating abilities described above.

The ability of the mill motor to accelerate itself and the mill should be checked before considering the selection of the motor final. This check will necessitate the accumulation of the WK^2 of the mill equipment, the WK^2 of the motor, the gear ratio, the mill speed, the roll diameters and the mill width. The formula for accelerating torque is:

$$T_A = \frac{WK^2 \times rpm}{308 \times t}$$

T_A = accelerating torque in lb-ft

WK^2 = Total inertia referred to motor shaft in lb-ft^2

rpm = Motor rpm

t = time of acceleration in sec

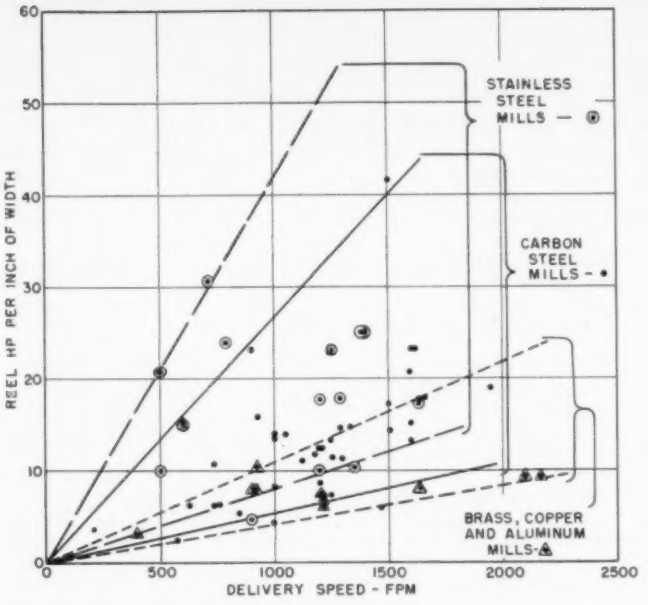


Figure 7 — Curves show reel hp per in. of width vs mill speed for a group of installed mills, and show a rough division by type of material rolled.

If a mill with the following data is assumed, a sample check of the accelerating ability can be made based upon acceleration in ten seconds.

Mill motor	1000 hp, 500/1000 rpm
Mill motor WK^2	5300 lb-ft^2
Mill speed	1000 fpm
Work roll diam	9½/10½ in.
Backup roll diam	33 in.
Width of mill	24 in.
Mill WK^2 (referred * to motor)	400 lb-ft^2
Gear ratio	2.74:1

*To refer WK^2 calculated at one speed to another speed use the formula:

$$WK^2 \text{ (at rpm}_2) = WK^2 \text{ (at rpm}_1) \times \left(\frac{\text{rpm}_1}{\text{rpm}_2}\right)^2$$

$$T_A = \frac{(5300 + 400)\ (1000)}{308}$$

$$= 1850 \text{ lb-ft}$$

The worst condition on the motor occurs just before it reaches top speed since at this point it has its weakest rated torque. Therefore, torque requirements should be checked against the top speed rated torque.

$$T_{rated} = \frac{\text{hp } 5250}{\text{rpm}}$$

$$= \frac{1000\ (5250)}{1000} = 5250 \text{ lb-ft}$$

Assuming the rolling load requires full load rated motor torque

$$T_{total} = T_{rated}\ T_A = 7100$$

Then $\frac{7100}{5250} \times 100 = 135.2$ per cent of full load during acceleration.

Since the frequently repeated load rating at twice base speed is 160 per cent, the sample motor has adequate accelerating ability.

If after checking the accelerating ability of the motor it is found that it cannot produce enough torque to accelerate itself and the mill in the required time and also carry its rolling load, several alternatives should be considered. First, of course, consideration should be given to lengthening the permitted accelerating time. If the accelerating time cannot be lengthened, ways of reducing the WK^2 should be investigated. A double armature motor is one possibility. Since the double armature motor will be smaller in diameter than a single armature motor, its WK^2 will be considerably lower. This will, of course, reduce the amount of torque required for acceleration. Different arrangements of motor speeds and gear ratios may also be tried. If it is found that the required accelerating torque is as low as possible and the specified time of acceleration must be met, the only alternative is to increase the accelerating torque ability of the motor. This can be done by increasing the frequently repeated load rating of the motor.

Economic considerations usually dictate the selection of motor voltage. In almost every case, the most economic choice will also be the best design choice. Small machines will usually fall into the 250-volt class and larger machines into the 600-volt class.

Using the motor in the sample calculations above and considering all of the above factors, the complete rating of this motor would be 1000-hp, 500/1000-rpm, 600-volt, d-c, 40 C forced-ventilated, single armature.

REEL MOTOR RATING

The selection of a reel motor must be made carefully since the reel motor should be as small as possible and still give the required strip tension. The primary reason for keeping reel motor size small is the necessity of maintaining low reel motor WK^2. The accelerating ability of the reel is important, since the reel speed must follow the mill speed closely in order to hold constant tension at all times. The reel inertia limits the reel accelerating rate, quite often to the point where it is the limiting factor in mill accelerating rate. Reel WK^2 also has some effect on tension range as will be shown later. Since the reel motor itself contributes a large part of the total reel inertia, it should be kept to as low a WK^2 as possible.

In selecting the reel motor horsepower the significant factors are tension and strip speed. These values are usually specified by the mill builder. Knowing tension and speed, horsepower calculation is the same as previously described under "Selection of Horsepower." The motor selected from the example in Table I was 350 hp.

The sample calculation includes an efficiency factor to account for friction. Friction is frequently hard to determine until the equipment has been installed and running. A figure of 10 per cent of the reel horsepower is sometimes estimated as total reel friction. This friction loss must be supplied by the winding reel motor but aids the unwinding reel motor.

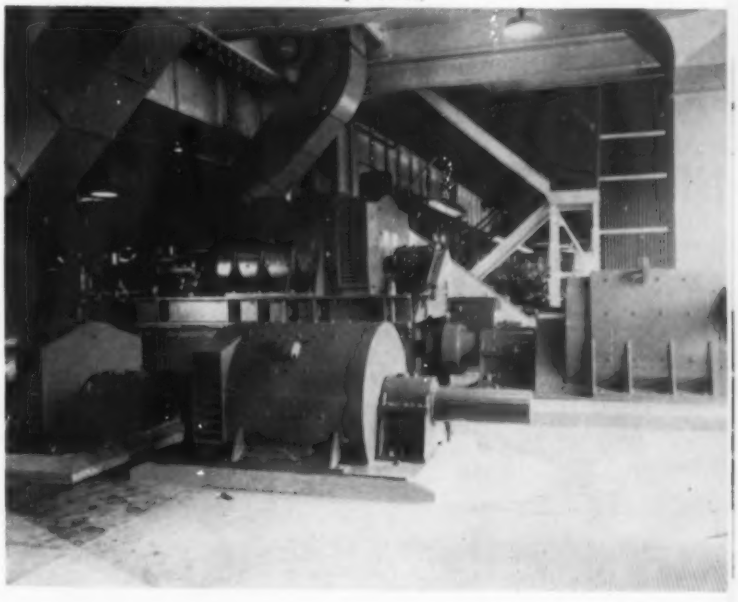
The temperature rating of a standard motor is 40 C rise over a 40 C ambient. If the motor is designed with Class B insulation, it can be rated 60 C rise and advantage taken of the Class B insulation to design a motor with lower inertia. Since reel motor inertia is quite important, as noted above, reel motors are quite often rated 60 C rise with Class B insulation. A 40 C rise motor should not be ruled out if it is adequate on the basis of inertia. Both 40 C and 60 C motors should be checked at the time the accelerating check is made.

If the 40 C rise motor is selected, an overload rating of 125 per cent load for two hours at 55 C rise may be specified if needed without modification of basic characteristics of the motor such as WK^2. This is not true for a 60 C rise motor. If the 2-hr, 125 per cent load requirement is needed for the 60 C rise motor, its overload temperature rating is 75 C rise. See ASA C50.4, 1955. The overload temperature rise rating determines the size of this motor. So, the WK^2 will be increased whenever the 125 per cent load requirement is specified for a 60 C rise motor. Regardless of whether a 40 C rise motor or a 60 C rise motor has been selected, the maximum repeated peak load specified should be adequate to accelerate the reel in the specified time.

The field weakening speed range of the reel motor is generally reserved to compensate for reel build up. The exception to this case is the use of some field range for mill speed adjustment. The following discussion concerns the selection of speed range to compensate for build up only. If additional speed range by field for mill speed adjustment is required, this range must be multiplied by the speed range calculated for build up.

Using the reel data from the hp calculation in Table I a sample calculation of reel motor speed range can be made. The reel build up is 20 to 45 in. or a 2.25 to 1 build up. To this range must be added some additional range for regulator action. The normal values for the additional regulating range are 5 per cent at the top speed end and 10 per cent at the base speed end. More margin is allowed at base speed than top speed because base speed is a more definite limit of the motor and

Figure 8 — Motor arrangement for a 6-in. and 35-in. by 30-in., 4-high reversing cold strip mill. Reel motors are 750-hp, 225/950-rpm, double-armature. Main twin drive has 1500 hp (each motor is 750-hp, 90/360-rpm, direct-connected to back up rolls.)



may not be as low as expected for less than full load. Modifying the original range by these figures gives the following:

$$\frac{2.25\ \ (1.05)}{0.90} = \frac{2.63}{1}$$

Compensation for mill roll wear should theoretically be made by voltage. The burden of making this voltage adjustment would be placed on the operator except where it could be made automatically through the use of billy roll pilot generators. Therefore, it is generally conceded that for convenience, roll wear compensation will be made automatically by the tension regulator with some variation of tension allowed. The range of speed required to compensate for roll wear must be added to the range of speed calculated above.

$$\frac{2.63\ \ (10.5)}{9.5} = \frac{2.90}{1}$$

The most economical choice of the motor will be made on the basis of the highest base speed motor which will give a 2.90/1 range without sacrificing good design. Other factors may indicate a low base speed motor, but this example will assume the most economical motor is satisfactory. Limiting the selection to a standard NEMA class N listed motor, a speed range of 350/1050 rpm would be selected.

The above speed selection applies to all types of mills. However, if brass or aluminum is to be rolled, extrusion must be considered. The effects of extrusion are especially pronounced for aluminum. This factor like roll wear can be most conveniently compensated for by reel motor field adjustment. Therefore, the reel motor field range, as calculated above, times the ratio of maximum to minimum extrusion factor will equal the actual speed range.

Draft affects the speed of the unwinding reel. This effect is generally taken care of by voltage and will be discussed later under generators and under control.

After the motor speed range has been selected, gear ratios may be chosen. Continuing the sample calculation, the next formula to be used is:

$$\text{rpm of reel} = \frac{\text{fpm}}{\pi\ D/12}$$

Minimum reel speed is at full coil with the smallest work rolls in the mill. Using the above formula and multiplying the strip speed by the ratio of minimum to maximum roll diameter.

$$\text{rpm (min)} = \frac{(1000\ \text{fpm}) \times \frac{9.5}{10.5}}{\pi\ 45/12} = 76.8\ \text{rpm}$$

Subtracting 10 per cent for regulator action

$$76.8 - 7.8 = 69\ \text{rpm}$$

$$\text{Gear ratio} = \frac{\text{motor rpm}}{\text{reel rpm}}$$

$$= \frac{350}{69} = 5.18$$

Maximum reel speed is at empty reel with the largest work rolls in the mill.

$$\text{rpm} = \frac{(1000\ \text{rpm})}{\pi\ 20/12} = 191\ \text{rpm}$$

Adding 5 per cent for regulator action

$$191 + 9 = 200\ \text{rpm}$$

Checking the above gear ratio, $200 \times 5.18 = 1036$ rpm

As in the case of the mill stand motor the accelerating ability must be checked. Using a 10-sec acceleration and accumulating WK^2 data the sample calculation can be continued.

WK^2 of motor = 1500 lb-ft^2

WK^2 of reel and gears = 250 lb-ft^2 referred to the motor shaft

WK^2 of coil = 680 lb-ft^2 referred to the motor shaft

For empty reel (Use reel top speed for simplicity)

$$T_A = \frac{(1500 + 250)\ (1050)}{(308)\ (10)} = 597\ \text{lb-ft}$$

$$T_{rated} = \frac{(350)\ (5250)}{1050} = 1750\ \text{lb-ft (at 1050 rpm)}$$

$$\text{Per cent } T_{total} = \frac{1750 + 597}{1750} \times 100 = 134\ \text{per cent}$$

For full coil (Use reel base speed for simplicity)

$$T_A = \frac{(1500 + 250 + 680)\ (350)}{(308)\ (10)} = 276\ \text{lb-ft}$$

$$T_{rated} = \frac{(350)\ (5250)}{350} = 5250\ \text{lb-ft (at 350 rpm)}$$

$$\text{Per cent } T_{total} = \frac{5250 + 276}{5250} \times 100 = 105\ \text{per cent}$$

It can be seen the worst condition of acceleration is with the reel empty. Since the required accelerating torque plus the load torque falls within the allowable 140 per cent frequently repeated load rating at weak field, the motor selection is all right. If on checking the acceleration, the motor should not be all right, the same measures as described above for the mill motor can be taken.

The selection of the voltage for the reel motor will be made on the same basis as the selection for the voltage of the mill motor unless influenced by the armature circuit. The effect of armature circuit is discussed under "Selection of the Motor-Generator Set." The complete rating of the reel motor can be listed for the example chosen as follows:

350-hp, 350/1050-rpm, 600-volt, 60 C rise, continuous, forced-ventilated, single-armature.

REEL TENSION RANGE vs MOTOR RATING

Maximum tension is limited by the reel motor horsepower. What, then, limits minimum tension? It was shown above that, theoretically, tension is proportional to reel motor amperes. Therefore tension is most often controlled by regulating motor current to a constant value set by the operator.

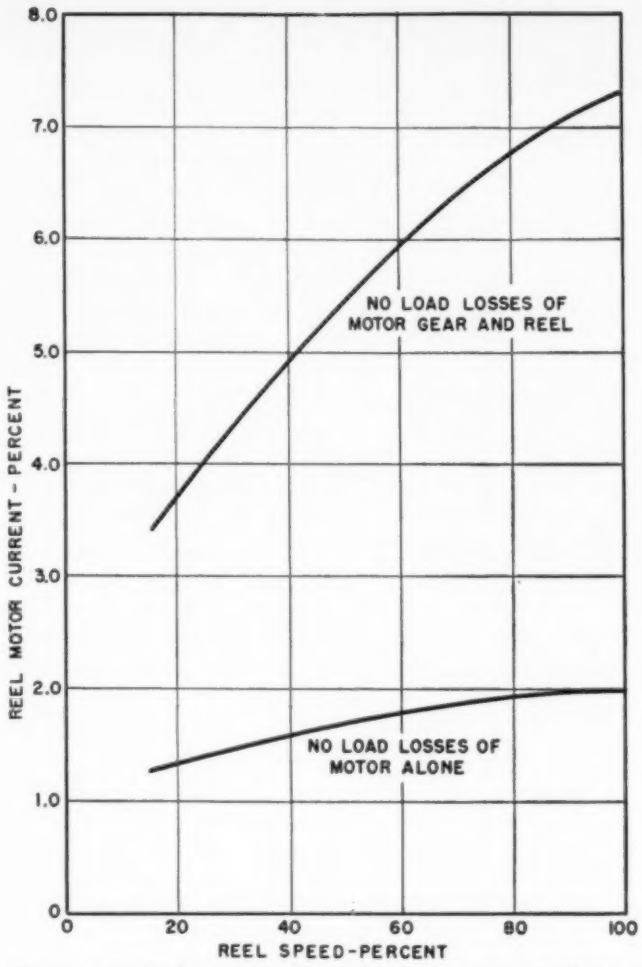


Figure 9 — No load losses of installed reel show both total losses and motor losses alone.

As long as tension is high, a current regulator is a good tension regulator. However, as the current is set lower, friction begins to upset the picture. In Figure 9 is a curve of both motor and total reel losses in per cent plotted against reel per cent speed. Although this curve was taken on a particular mill, it is typical of reels in general.

Figure 9 shows two important points. It shows that as current is reduced to lower values, a point is reached where the current that is converted into tension can increase several times during the coil build up even if the regulator is perfect and there is zero change in the selected value of current. This point makes it necessary for the designer of a current regulator to have the curve of no-load losses for the reel in question before he can make any definite commitments about the minimum tension his regulator will hold. For the average mill, tension ranges of 10 to 1 are reasonably successful. If the tension range must be greater than 10 to 1, a close look should be taken at the losses.

Figure 9 also shows the relative importance of motor losses and reel and gear losses. For this particular mill, complete elimination of motor losses would have made only a 35 per cent maximum reduction in the total. More important, the change in losses during coil build up would still be present. The difficulty of improving minimum steady state tension by changing motors or using special arrangements of motors is clearly demonstrated.

Inertia compensation may also effect minimum tension which can be held. Inertia compensation was described above as the increase or decrease in reel motor current necessary to provide accelerating or decelerating torque while maintaining tension constant. Inertia compensation must be applied in precisely the correct amount and at exactly the proper time. If either timing or amount is off, an error in tension results. The amount of compensation should be constant regardless of the tension to be held. If there is an error in compensation, it will be much more significant at low tensions since the ratio of the amount of error to tension held may become high. The amount of inertia compensation can be set fairly accurately. But transient timing error during periods of application or removal of inertia compensation is difficult to eliminate. A reduction in accelerating effort (amount of compensation required) may reduce the error to negligible proportions. Such a reduction of accelerating requirements should always

TABLE II

Variations in Accelerating Current with Motor Selection

Reel motor base speed	Approximate gear ratio	WK^2 motor	WK^2 reel and gears (at motor shaft)	WK^2 reel, coil and gears (at motor shaft)	Total WK^2	Per cent accelerating current full coil
Full reel						
400	4.18	1240	.....	920	2160	7.1
300	3.13	1400	.....	1460	2860	5.3
250	2.61	1950	.....	2010	3960	5.1
225	2.35	2200	.....	2420	4620	4.8
200	2.09	2600	.....	3000	5600	4.6
Empty reel						
Top speed						Empty reel
800	4.18	1240	280	.....	1520	20.1
600	3.13	1400	320	.....	1720	12.8
500	2.61	1950	370	.....	2320	12.0
450	2.35	2200	390	.....	2590	10.8
400	2.09	2600	450	.....	3050	9.6

Motor 300 hp Coil 20/40 in. diam. Strip 24 in. wide at 1000 fpm. Reel speed = 191/95.8 rpm.

Note: To eliminate variables in this comparison, the motor speed range has been selected to correspond to the buildup neglecting extra range to compensate for roll wear, etc.

be investigated where an extension of minimum tension range is important.

Accelerating current is proportional to torque. The formula for accelerating torque has been shown as

$$T_A = \frac{WK^2 \text{ rpm}}{308 \text{ t}}$$

WK^2, rpm, and time of acceleration may all be changed to reduce accelerating torque. Longer accelerating time means reduced inertia compensation. However, time may be established by production requirements and may not be subject to change. WK^2 and rpm are greatly influenced by motor base speed and gear ratio. It can be shown to be generally true for moderate mill speeds that a reduction in motor speed and the corresponding decrease in gear ratio will reduce the accelerating requirements. However, in motor design, WK^2 is not a direct function of base speed for a given hp size and each case should be checked independently. In the example, Table II, the WK^2 referred to the motor goes up as the rpm goes down, but in all cases a net decrease in per cent accelerating current is shown.

A double armature motor with a mechanical disconnecting device between armatures has been used many times in an effort to extend the minimum tension range. Both armatures are used to drive the reel for heavy tensions and one armature is used alone for lighter tensions. Where the armatures are of unequal sizes, the smaller armature is used for light tensions. It has been shown above that the benefits of this arrangement as far as steady state tension is concerned are small. Such an arrangement will, however, reduce the effect of any transient error in application and removal of inertia compensation. The omission of one armature reduces the total motor WK^2 and so reduces the accelerating torque required. Since the tension torque will be the same for one or two armatures, the ratio of accelerating torque to tension torque becomes less.

Any transient error in inertia compensation will be proportional to the amount of inertia compensation required, and a reduction in the ratio of accelerating torque to tension torque means the effect of any such transient error is reduced. Double armature reel motors with armatures of unequal horsepower where the larger armature is disconnectable are of greater help in extending the minimum tension range than equal horsepower double armature motors. While the value of double armature motors with clutches is apparent in the extension of minimum tension range, the advantages must be weighed against the disadvantage of having a mechanical disconnecting device. In the sizes of most reel motors, this clutching mechanism will usually entail added maintenance and installation problems.

It would seem that the best engineering solution for tension ranges exceeding 10 to 1 would be a low base speed, direct-connected reel motor. The elimination of gear losses and the probable reduction of accelerating torque will certainly reduce the minimum limit of the tension range. As in all engineering problems, the advantages must be balanced against economics. A motor with such a low base speed may not even be available, but if it is available it will be more expensive. In all cases, the mill operator must consider the relative worth of any refinement and make his decision accordingly.

SELECTION OF MOTOR FOR PULL-THROUGH MILL

The single motor for a pull-through mill has in general the characteristics of a reel motor. It must provide a rolling torque, tension torque, and accelerating torque for both of the reels and the mill. As for other mill motors, the motor rating is usually specified by the mill builder, but can be calculated from power data and rolling schedules. Temperature, overload and commutating ability, and voltage ratings are selected on the same basis as for the main mill motor discussed above. In general, wide motor field ranges are used to cover build up as well as some of the mill speed range. The accelerating ability must be checked as in the case of the conventional mill and reel motors above.

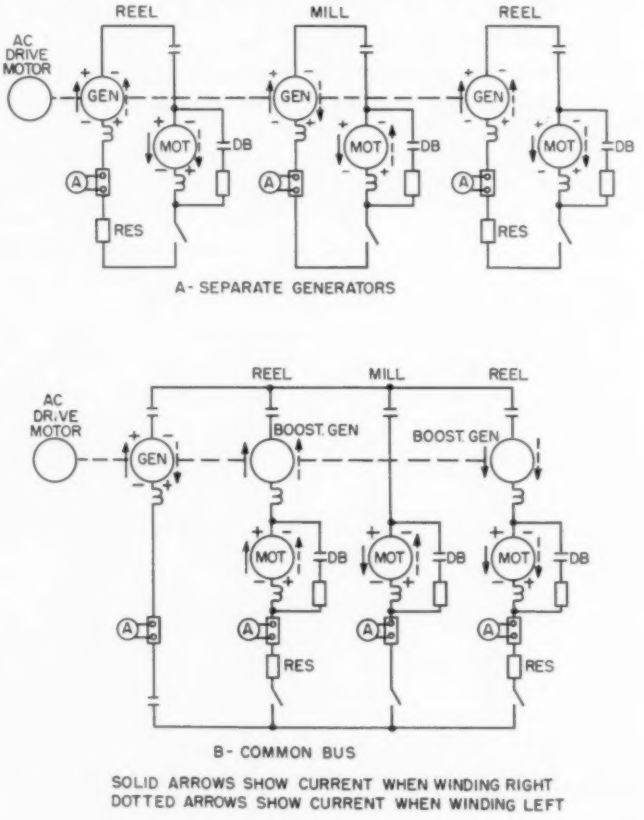
The procedure of checking accelerating ability will be the same as above except the WK^2 of both reels and mill must be combined and referred to the motor shaft. Changing WK^2 from one speed base to another is accomplished by multiplying the WK^2 by the ratio of the square of the original speed to the square of the new speed.

$$WK^2_2 \text{ (at rpm}_2) = WK^2_1 \text{ (at rpm}_1) \times \left(\frac{\text{rpm}_1}{\text{rpm}_2}\right)^2$$

SELECTION OF THE MOTOR-GENERATOR SET

Although most of the recent mills have been supplied with separate generators for each motor, many older

Figure 10 — Simplified armature circuits show: (a) separate generator system and (b) common bus system.



mills were installed with a common bus armature system and a booster generator or booster generators at the reel motors. Figure 10 shows at the top under (A) a separate generator armature system and under (B) a common bus system with a booster for each reel motor. Either boosters or separate generators can be made to do an equal job. The early common bus systems which made use of one booster only and switched that booster from one reel to the other on reversal of the mill were abandoned because the armature switching caused momentary loss of all tension. The unwinding side was also left with no means of IR compensation.

It is generally considered somewhat easier to operate and maintain a mill with separate generators. Corrections for such things as draft can be easily made by means of generator voltage without increasing the size of the machines involved. The amount of field range specified in the mill motor has no effect on the size of separate generators, while it is a dominant factor in the selection of reel booster generators.

The choice between common bus with separate boosters or separate generators is basically economic. If the prices of both systems are equal the choice will be for separate generators. The economic study will usually show that where large boosters are required, separate generators are the least expensive. The study will also show that with a common bus system, the voltage of the reel motor is fixed by that of the mill motor and the bus. However, such a voltage may not yield the best designed or lowest priced reel motor. Where separate generators are used the voltage of the reel motor can be selected for the best combination of design and cost.

When separate generators are to be used, the generator ratings will be selected on the basis of motor amperes times rated volts divided by 1000. The amperes and the volts, of course, are those required by the mill or reel motor in question. The generators must be good for the same overload and commutating ratings as the motors.

The standard specification for generators usually includes a 40 C rating with Class A insulation. The generators will nearly always be rated as open machines. However, if enclosures are desirable, then forced ventilation is required for the main units of the motor-generator set.

The selection of boosters in the common bus system is more complex than the selection of generators in the separate generator system. The bus voltage is determined by the mill motor rating and is shown in Figure 3 by the line called mill volts. As explained previously, the reel motor voltage must be as shown by the line called reel volts. The difference between the bus voltage and the reel motor voltage must obviously be made up by the booster. For the case shown in Figure 3, it will be noted that the maximum voltage difference occurs at 50 per cent rheostat travel and is equal to 300 volts.

The voltage on the unwinding side must be lower than that on the winding side by an amount equal to draft. This can be expressed as

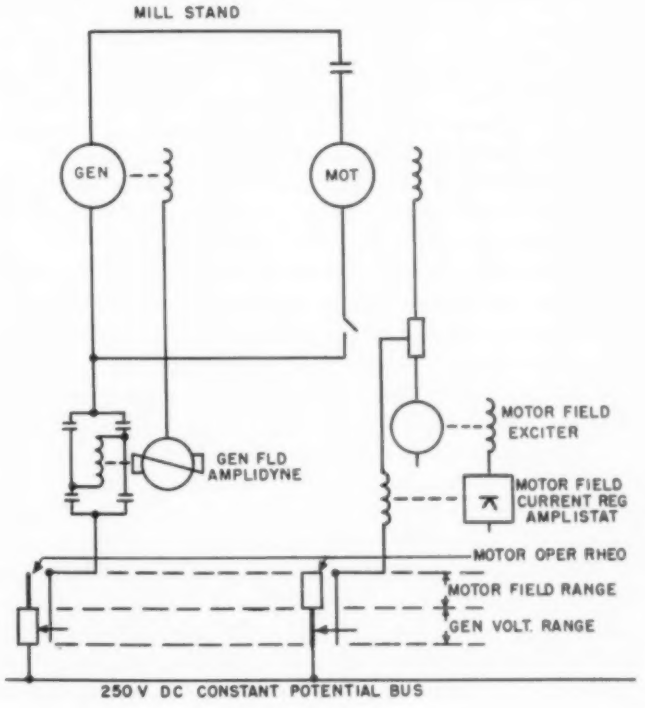
$$\frac{\text{delivery speed} - \text{entry speed.}}{\text{delivery speed}}$$

If the draft is 50 per cent, the reel volts on the unwinding side must be lower than the reel volts on the winding side by 50 per cent. This voltage difference also must be provided by the reel booster. In the example shown in Figure 3 the reel voltage at the 50 per cent travel point must be ½ of 300 or 150 volts for a 50 per cent draft thus requiring a booster of 450 volts. Since the booster must be rated for full motor amperes the booster kilowatt rating will be the voltage as selected above times the motor amperes divided by 1000. In the case listed, the booster will be ¾ of the size of a full reel generator.

The main generator in a common bus system must supply all rolling and accelerating power. Since the unwinding motor is generating, it may supply power to the bus. However, common practice is to neglect the unwinding motor and rate the main generator to supply the full capacity of the winding reel and mill motors. Although this rating may seem somewhat larger than necessary, it is to be noted that with the first pass from a coil box, the generator must supply full winding reel and mill motor power without any help from the unwinding motor.

The driving motor for the motor-generator set must supply through its shaft all of the power consumed by the mill in reducing the strip plus losses. For the separate generator system the motor-generator set driving motor will be selected on the basis of the full capacity of the mill generator and the one reel generator. Since the unwinding reel generator is motoring it can be neglected. Although the driving motor selected on this basis may frequently operate lightly loaded, its full capacity will be required for any heavy passes at high speed where light tensions are carried on the unwinding side, while heavy tensions are carried on the winding side. It is sometimes reasonable to reduce the size of the driving motor where such a condition is not anticipated, but it should be recognized that the mill

Figure 11 — Simplified one-line diagram shows mill stand control with generator voltage regulator and motor field current regulator.



will be limited in some respects by the motor-generator set driving motor and also that the motor-generator set motor may not be adequate for some new application in the future. Motor pull out torque is fixed by the peak overload of the generators.

The driving motor for a motor-generator set for a common bus system with boosters should obviously be the same size as that for a separate generator system. It is required to supply only enough power to operate the mill and reels, and power requirements are the same regardless of which kind of a generating system is selected.

RECTIFIERS

Can rectifiers be used for a reversing cold strip mill? They can be used, but their irreversible characteristic makes special considerations necessary. For reversal of mill direction, armature reversing contactors can be used or the motor field current could be reversed. However, regenerating currents occur during deceleration and on the unwinding side, and this power must be dissipated. There are several means of solving this problem, but all involve additional equipment over a generator power supply. The easiest application would be as the power supply for the stand drive motor. Rectifiers as a reel power supply are somewhat more troublesome, but the problems can be solved. Rectifier ratings are selected basically the same as the generator ratings once an armature circuit is decided upon. After the engineering problems are solved, the selection of rectfiers versus generators becomes basically one of cost and experience. While rectifiers have been used to a very limited extent in Europe to supply power to the mill stand, the economics are different in the U. S. and no installations have been made.

CONTROL OF MILL STAND

The main objective of the control of the mill stand is to produce the required generator voltage and motor field current necessary to obtain the rolling speeds and torques desired by the operator. As mentioned earlier, both generator voltage and motor field current are under the control of a master motor operated rheostat. The rheostat is laid out so that as it progresses from 0 to 100 per cent of its travel, the voltage of the generator is first raised to full value after which the motor field current is progressively weakened. Figure 3 demonstrates the way this rheostat would be laid out. The rheostat would be tapered where necessary to fit machine design data to give a mill speed directly proportional to the amount of rheostat travel. In this way, the mill motor is always operated at full field until full voltage is reached, providing the maximum torque at the lower speeds.

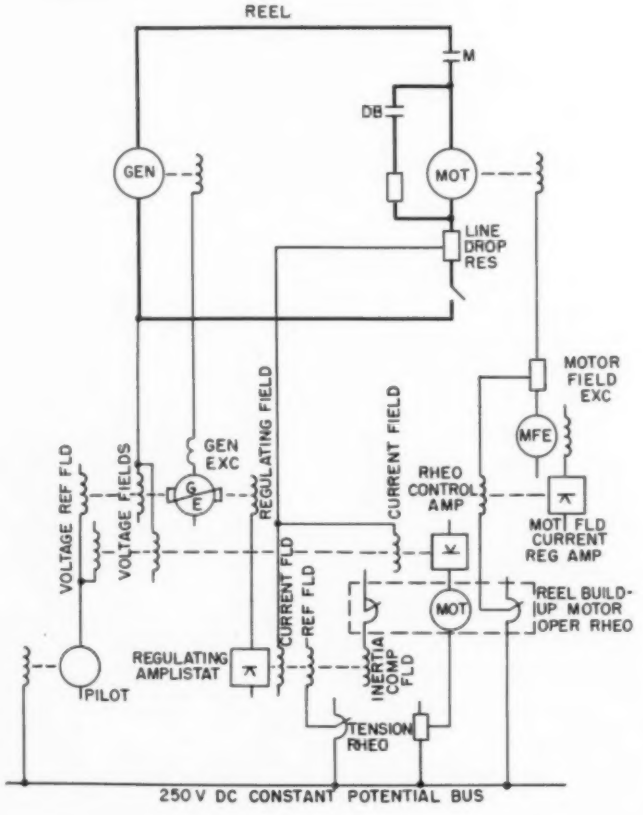
When large generators are needed, the rating of the rheostat elements would be exceeded unless an exciter is used for the generator field. The additional machine introduces an additional time constant into the circuit making it more difficult to get large machines to follow closely the rheostat travel. Therefore, the generator voltage is usually regulated to a reference which is changed as a function of the rheostat movement. The use of a regulator forces the generator voltage to follow closely the rheostat movement and to maintain the voltage indicated by the rheostat. With the regulator it is possible to obtain zero generator voltage, and the mill can make smooth starts and stops. The regulator is not usually necessary for small generators.

For large mill motors, a motor field regulator should be used. The main purpose of the motor field regulator is to force motor field current to the value indicated by the rheostat so the motor speed will closely follow the rheostat travel. By using a good regulator, response and accuracy of field control of a large motor can be made equal to or better than that of a small motor where the motor field is controlled directly by the rheostat. See Figure 11.

A speed regulator can be substituted for the mill generator voltage regulator. The speed regulator controls generator voltage to maintain speed proportional to motor operated rheostat position. If no motor field regulator is used, the motor field will be under direct control of a dial on the master motor operated rheostat. The motor field will then lag behind the rheostat during acceleration, but the speed regulator will force the generator voltage upward to make up for the lag in motor field. This means that additional voltage must be available during acceleration and the generator must be capable of providing it. The amount of overvoltage decreases as the accelerating period is lengthened.

Where twin drive motors are used, the problem of load balance arises. Load balance will be accomplished by means of a load balance regulator or by having sufficient droop in the motors' regulation curves. Since the mill is reversing, any load balance scheme using

Figure 12 — Simplified one-line diagram shows reel current regulating tension control with motor field current regulator.



motor series fields will be incorrect unless the series fields are reversed each time the motor is reversed. Otherwise the series field will be in the wrong direction half of the time. Therefore, when necessary, additional droop is best obtained by line resistance. Because the power loss may become excessive, the use of line resistors is not suitable for large motors.

If double armature motors are used, they can be connected in series to obtain load balance. This, of course, means the voltage of each armature will be rated half of the voltage of the mill generator. Sometimes it will not be practical to rate these armatures at one half voltage because of lack of duplication or excessive cost. Under these conditions the load balance regulator will be required.

As the motor operated rheostat progresses towards its top speed position in the field weakening range of the mill motor, the weakening of the motor field reduces the motor torque causing the armature current to build up. This build-up of current, of course, limits the operating speed of the mill to a value where the current does not exceed the motor rating. However, sometimes this rating is inadvertently exceeded and the circuit breakers will trip the motor off of the line. On a few mills, a load relay has been applied which will stop the rheostat travel when the current reaches a limiting value, thus preventing a further increase in current and keeping the circuit breaker from tripping.

CONTROL OF REEL MOTORS

The requirements of the reel motor were discussed earlier. It was seen that the tension is proportional to line current if the voltage of the motor is kept proportional to mill speed, and the motor field excitation is kept proportional to coil diameter.

To keep the voltage of the reel motor proportional to mill speed, the speed is measured and the voltage of the generator adjusted proportionately. Figure 12 shows a one-line sketch of a typical reel control. In this control the speed of the mill is measured by a pilot generator which is geared to the mill motor. The generator voltage is then regulated by means of a rotating regulator to a value corresponding to the pilot reference voltage. Due to the draft being taken by the mill, the unwinding strip speed is slower than the winding strip speed. Therefore, some compensation must be made on the unwinding side. This is usually done by a rheostat adjustment of voltage. This adjustment is frequently made an operator's function, but for simplicity, it can be made a motor room panel adjustment with the full knowledge that most of the time it will be a compromise setting.

If the tension regulator is kept in range so the voltage does not change during a pass, the motor field range must not be a limiting factor. Theoretically, the field range must be increased by the difference between actual draft and the draft compensation when the latter is a motor room panel setting. It will usually be satisfactory to let some change occur in generator voltage when the motor field runs out of range, in order to keep motor field range to a minimum. This will happen only when extreme drafts occur at a time when the motor field is near its limits. In most cases, such a compromise can be avoided by the operator's accepting responsibility for setting draft compensation for each pass.

Sometimes pilot generators coupled to the billy rolls on either side of the mill are used for the reference voltage for the reel generator voltage regulator. This arrangement has the advantage of giving automatic draft, roll wear, and extrusion compensation since it actually measures strip speed and not driving motor speed. It, however, has some disadvantages. It is more difficult mechanically to mount and maintain pilots on the billy rolls. The scheme also has the disadvantage that if a momentary loss of tension occurs during rolling, the billy roll no longer engages the strip and the billy roll speed and reference voltage decrease during this interval. Nevertheless, because of the desire for automatic draft compensation, billy roll pilots are being used more and more frequently.

Many smaller mills have the reel generator voltage controlled directly from the master motor operated rheostat by means of a separate dial. This system, of course, is not quite as accurate as a reel voltage regulator because of the difficulty in laying out a rheostat dial which will exactly match mill speed at all times. There is no means of forcing the reel voltage to follow the mill speed smoothly. Since the inherent speed of response of the systems for smaller mills is faster, such forcing is less important than for large mill systems.

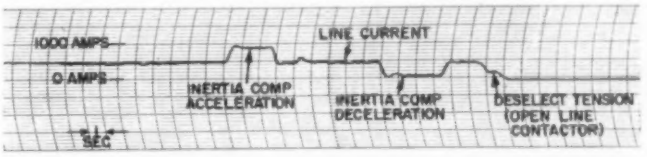


Figure 13 — Oscillograph chart gives reel motor amperes with buildup rheostat type of control as shown in Figure 12.

The tension regulator will make up for the inaccuracies in the rheostat dial. This system has been used successfully on many small mills and has produced excellent results where fast rate of change of speed is not required.

While all of the control functions of the reel work together to control tension, the specific term "tension control" is usually thought of as meaning control of the motor armature current. A currently used tension control system is shown in Figure 12. This is a simplified one-line diagram and omits stabilizing circuits for clarity. The control operates as follows. Since armature current indicates tension, its value is measured by an armature series resistor and compared with a fixed reference voltage selected by the operator by means of the tension adjusting rheostat. The regulator's job is to hold the current constant at the value set by the tension rheostat over all conditions of reel operation. The regulating magnetic amplifier must hold current constant for all changes in the system both mechanical and electrical. It accomplishes this function by changing generator voltage through the generator field exciter in order to maintain constant reel motor armature current. One reason the reel current tends to change during reel operation, is the building-up or building-down of the coil.

As the coil builds up on the winding reel, the reel will be held back by the mill and its rpm will decrease.

The line current will increase slightly. The current regulator will then cause the generator voltage to decrease to hold constant current.

The tendency of the reel current to increase as the coil builds up can be explained by the formula:

$$\text{Generator volts} = \text{motor cemf} + \text{IR drop}$$

As the reel slows down the motor counter electromotive force voltage (cemf) decreases and line current must increase so the sum of cemf and IR drop still equals generator voltage. Since the current regulator acts to reduce generator voltage, it maintains constant current by keeping the difference between generator voltage and motor cemf constant.

The increase in diameter of the coil requires an increase in reel motor torque to keep the tension constant. The reel motor torque is changed by adjusting the reel motor field. The correct motor field current is that value which will keep the cemf voltage constant. The adjustment of motor field is accomplished by a separate follow-up regulating system.

As motor cemf is lowered by coil build-up slowing down the reel, the rheostat control magnetic amplifier detects the change in reel motor cemf by means of its fields which measure generator voltage, subtract armature circuit IR drop and compare the difference with the pilot volts. This magnetic amplifier then drives the reel build-up rheostat in the proper direction to restore the motor cemf to its original value. In the case of the winding reel, the rheostat will run in a direction to increase the shunt field excitation of the reel motor. The current regulator then restores the generator voltage to normal.

As build-up continues cemf again decreases accompanied by a increase in current. The current will again be corrected by generator voltage with a follow-up correction of motor torque through change in motor field. Thus motor field is adjusted proportional to coil build-up, and voltage is kept constant for a given mill speed. In this way constant armature current is truly representative of constant tension.

When the reel is an unwinding reel, the rheostat motor is reversed in polarity so it moves in a direction to weaken motor field and correct for build-down of the coil.

When large machines are involved, the reel motor operated rheostat controls the motor field current regulating magnetic amplifier to give precise and fast control of the reel motor field while handling the large currents with ease. For small machines, the field current regulator can be omitted and the rheostat operated directly in the motor field circuit.

The above type of tension regulating system is designed to correct for steady state error. This means that the line current not only is being related, but that the error in current is being observed in the voltage errors and is being periodically eliminated through the action of the motor operated rheostat. Figure 13 shows a recorder chart of line current in an actual operating regulator.

The reel motor operated rheostat is kept in a position when the mill is stopped which is the same as the position it had when the mill was running. In this way the motor field current is maintained at the same value when the reel is stopped as it was when the reel was

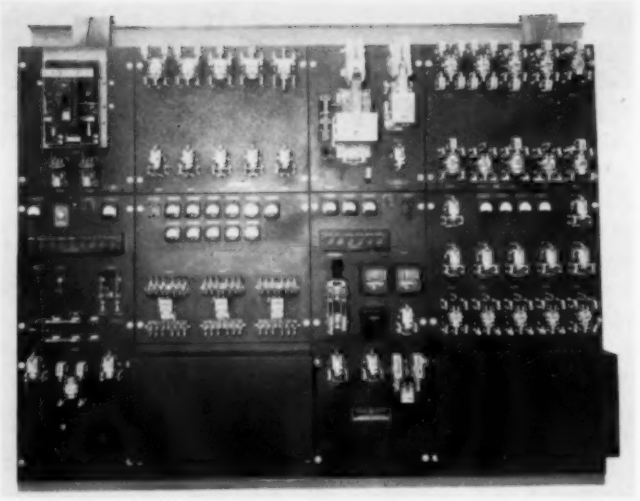


Figure 14 — D-c control panel for reversing cold strip mill is approximately 90-in. high, 264-in. wide, and 75-in. deep.

running. Thus, at all times the rheostat position is a measure of coil diameter. One feature of this system is that an auxiliary dial on the motor driven rheostat can be used to recalibrate the inertia compensation as a function of coil diameter. Another feature is that when the circuits are transferred to reverse the direction of the mill, there will be no change in torque and the tension will be maintained during the transfer. The rheostat is automatically returned to the weak field position when the mandrel is stripped in order to be ready for the next coil.

Armature current is maintained constant and the motor field is also constant for a given coil diameter, and so unless some changes were made, the torque would remain constant during acceleration and deceleration. A winding reel requires additional torque and an unwinding reel requires less torque during acceleration to compensate for the effects of inertia. Otherwise, there would be a drop-off in the winding tension and an increase in unwinding tension during acceleration. Similarly, an increase in winding tension and a drop-off in unwinding tension during deceleration would be observed without compensation. Some action is necessary at such times to "fool" the regulator into holding either more or less current, as required, than that selected by the tension rheostat. An inertia compensating circuit must be provided to do this job.

The most common inertia compensation circuit uses a block signal which will change the amperes by a preselected fixed amount either plus or minus depending on whether the reel is winding or unwinding and whether it is accelerating or decelerating. If the rate of acceleration of the mill is changed, the amount of inertia compensation should be changed. Further, to be correct for all values of inertia encountered on the reel as the coil diameter varies from minimum to maximum, inertia compensation should change with coil diameter. Adjustment of inertia compensation with reel diameter is accomplished through means of a dial on the reel motor operated rheostat.

There are some special operations which are required of a reel circuit for a reversing cold strip mill. One of these is the ability to rewind a coil from one reel to to the other without doing any work on it in the mill.

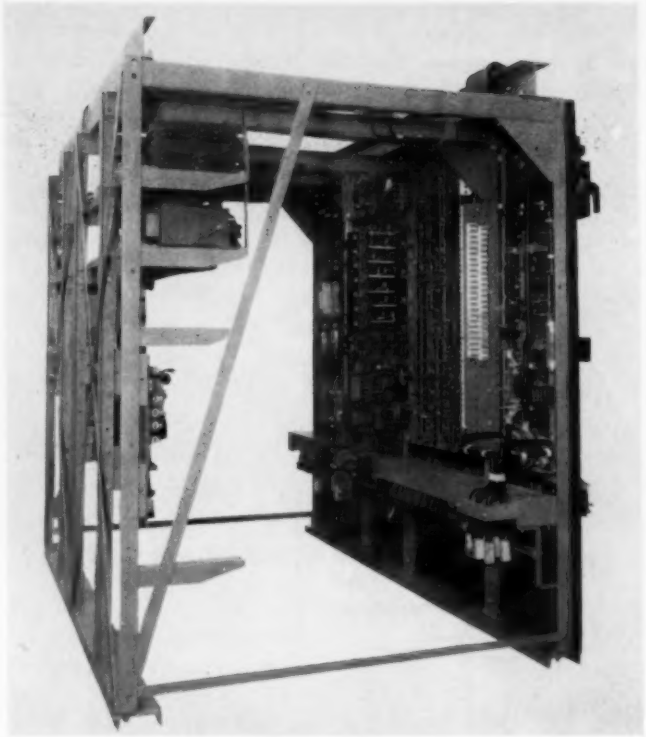


Figure 15 — Rear view of portion of d-c control panel for reversing cold strip mill. Panel is approximately 90-in. high, 264-in. wide, 75-in. deep.

Another is to start a full coil from either reel for the first pass. Automatic location of the reel jaws for threading is another. These and other functions can be handled by simple provisions in the control, but should be mentioned to the electrical manufacturer so that if desired they will not be overlooked since they are not common to all mills.

Occasionally double armature reel motors are found effective in reducing the inertia for adequate accelerating ability. The double armature reel motor introduces the problem of load balance as did the double armature mill motor. This problem also can be most conveniently solved by connecting the two armatures in series. The only reason for a different connection would be an economical one which might dictate the armatures be built with higher voltage windings and connected in parallel. This would require that some sort of load balance be provided. A load balance regulator can be used, but for many small equipments, line resistors are relied upon for load division since they are already present as part of the control.

TENSIOMETER CONTROL OF REEL

Theoretically an ideal reel tension regulator is one which measures the tension directly with some kind of tensiometer and makes the necessary corrections in the motor. Such a tensiometer regulator has the advantage of holding tension constant during steady state running conditions and during acceleration. With these advantages the steady state tension range can be extended over a greater range than would be possible with a current regulator, since the tensiometer regulator does not see the effect of reel and motor friction. Except for transient variations, inertia compensation is automatic. In many cases the motor arrangement can be simplified.

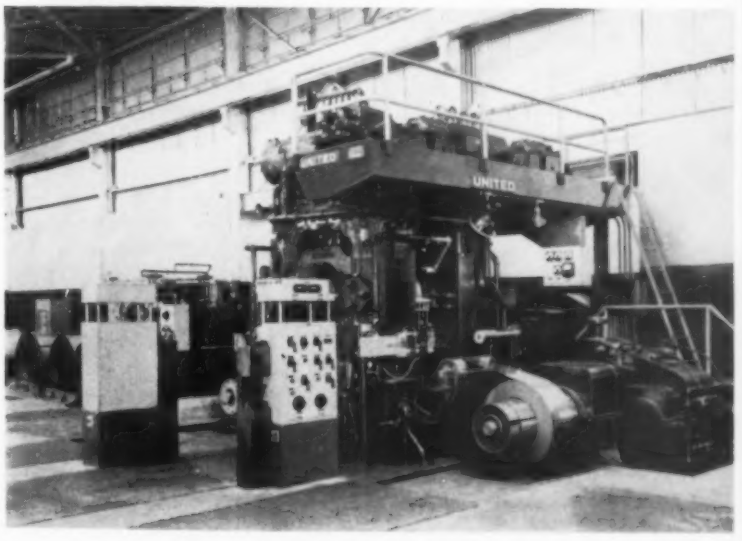
The tensiometer regulator has some problems which must be solved. The tensiometer measuring device must be located in a position where it gets a constant tension signal regardless of pass line changes in elevation and angle as coil diameter changes. There might be some objection from some users to the presence of the additional mechanical parts needed to form the tensiometer. To compensate for the fact that the reels would not tend to start until the mill had started and created a change in reel tension, a small forcing signal must be furnished during the transient periods of starting and stopping of acceleration. With the coming of computers so that stability analyses can be made of control systems, it seems that most of the stability problems formerly associated with tensiometer regulators can be solved before an installation is made. With this problem taken care of, the future of the tensiometer regulators seems assured. They will undoubtedly be considered on jobs where critical tension problems exist. This includes jobs where a wide range of tensions or materials are to be found on the same mill. At the present time, it seems probable that for large high production mills with moderate tension ranges, the current regulator will still be used to control reel tension.

CONTROL OF PULL-THROUGH MILL

The control of a pull-through mill is actually a combination of the control furnished for a mill stand and for the winding reel on a mill with driven rolls. The control must not only set mill speed but must adjust the motor speed in proportion to coil build-up.

One recent novel control for a pull-through mill makes use of the master motor operated rheostat as the component which adjusted both generator voltage and motor field current. The rheostat is laid out similar to that for the mill drive of a conventional mill with voltage control up to base speed and motor field control above base speed. The reel regulating control is a speed regulator since tension is automatically set by the mechanical drag on the strip. The speed regulator is in control of the position of the motor operated rheostat. This means that as the coil builds up during winding,

Figure 16 — This 4-high reversing cold strip mill utilizes control cabinets close to reels.



the motor operated rheostat will be forced back towards its lower speed end. Depending on mill speed selected, the motor field may be adjusted for part of this range and, before the coil has completed its build-up, the voltage may be reduced. The advantage of this control is that the motor is at all times working with the highest torque per ampere possible, that is with maximum field current and minimum armature current for the speed selected.

OPERATOR'S CONTROL STATIONS

Many different plans may be offered for the operator's control stations. The usual choice is between vertical control cabinets and horizontal operator's desks. The choice as to whether to use desks or cabinets is dependent upon preferred location of the station.

The arguments for control desks point out that the desk can provide adequate space for all devices which the operator may desire to be located at one place and still keep them logically grouped and conveniently spaced. The arguments for the control cabinet are that they may be located close to the mill and therefore have the advantage of placing the operator where he has a close and accurate vision of the strip. The choice between one and two stations is generally dependent on the size of the mill, one station being used when the mill is small enough that the operator can see everything from one location.

MOTOR ROOM LAYOUT

A discussion of reversing cold strip mills would not be complete without some mention of motor room lay-

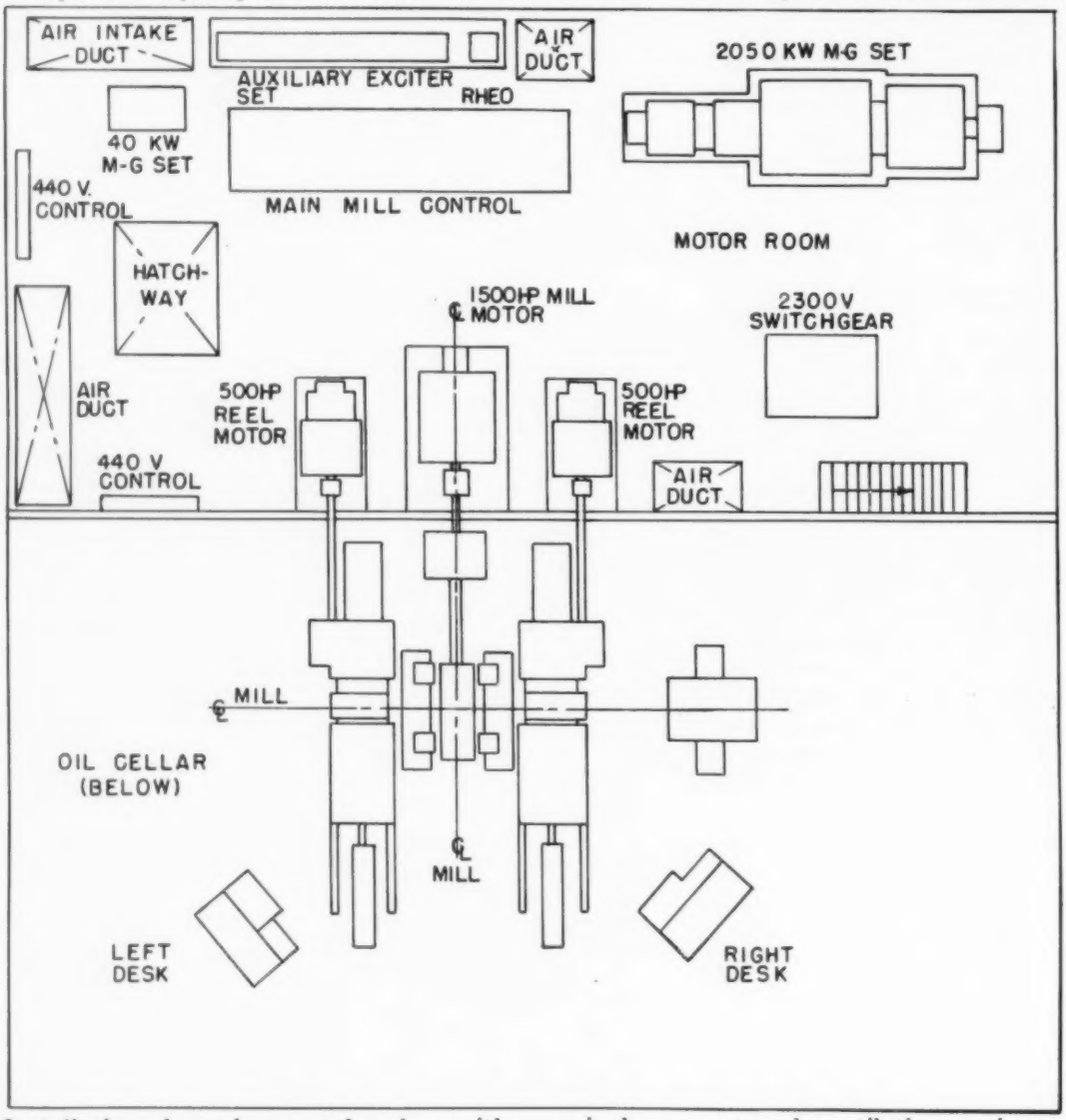


Figure 17—Motor room layout of 4-high, 29-in. reversing cold strip mill shows main units of electrical equipment.

Installations have been made where either a single station or two stations are located either close to the mill or at some short distance away from the mill. Figure 16 shows a vertical floor mounted control cabinet at each reel and located close enough to the reel so the operator is in close contact with the mill. Figure 2 shows a single control desk located remote from the mill, while Figure 1 shows two control desks and Figure 19 shows two control cabinets mounted on the mill housing. The choice of type and location of control stations must finally be made by the user.

out and ventilating equipment. The location of the motors themselves is determined by the physical location of the mill and reels. Both reel and mill motors must be provided with ventilating air. Mill motors may be located either in a motor room or in the mill area. Either a recirculating ventilating system or a non-recirculating system can be used. Where the motors are in a motor room, it is recommended that either system be a down-draft to keep the motor room cool. A down-draft system will take air from the motor room, pass it downward through the machines, and discharge

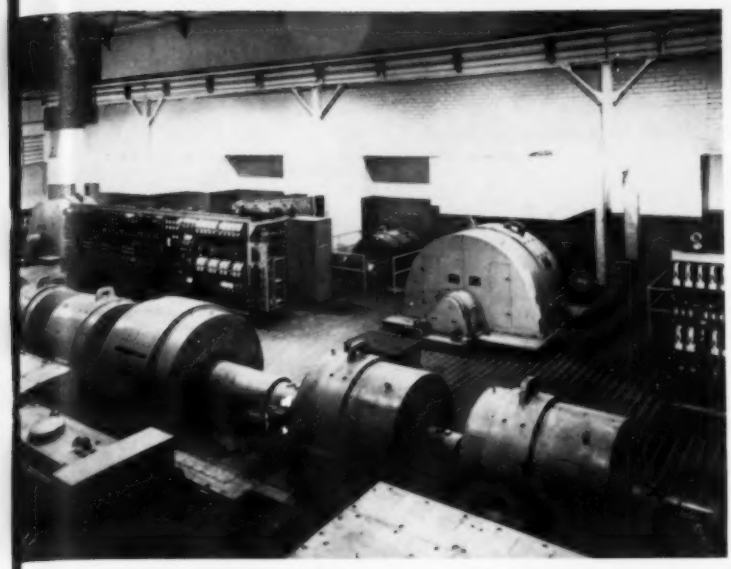


Figure 18 — Motor room for two 48-in., 4-high reversing cold strip mills shows unit substation, both mill motors, one reel motor, control panel and motor generator for one mill.

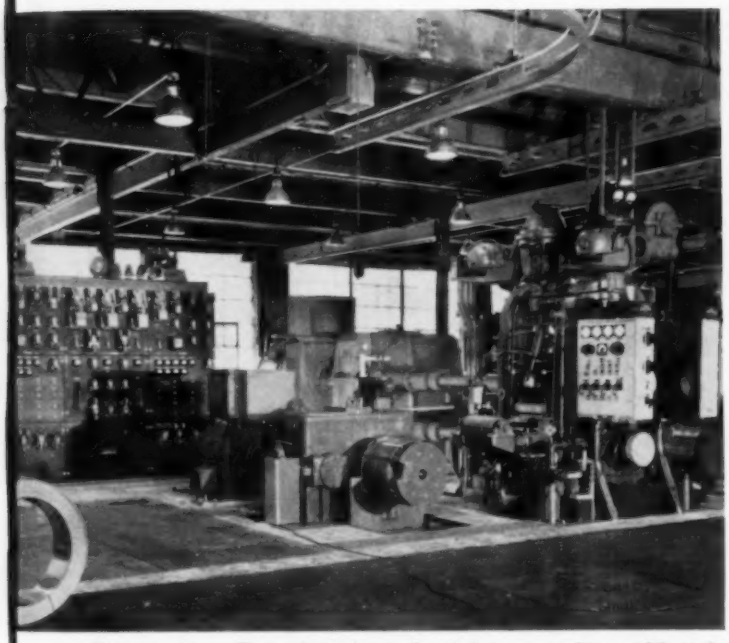


Figure 19 — This 4-high, twin drive reversing cold strip mill has motors with motor mounted blowers.

it downward into the basement or air tunnel. If the air is to be recirculated it will be cooled by surface air coolers and then returned to the motor room. If the system is non-recirculating, the warm air will be discharged into the mill area or directly outside or both, depending on the time of year.

If the machine design permits, it may be desirable to arrange the motor-generator set with the mill generator in the center and the reel generators on the outside to correspond with the motor arrangements. When such an arrangement is possible, it will enable cable or bus runs to be made more easily. The cable and bus runs will also determine to some extent the arrangement and location of the control panel and starting equipment for the motor-generator.

In making a motor room layout, some thought should be given to the desired panel lineup. Operating and maintenance men generally find a front view panel lineup should be in the same order as the actual lineup of the mill, as viewed from the operator's station. This would make the left reel panel on the left and the right reel panel on the right and the mill control in the center. Figure 17 shows a typical motor room blockout and Figure 18 is a picture of an installed mill motor room.

SUMMARY

In the operation of the reversing cold strip mill, depending on the type of mill to be used and materials to be rolled, many individual electrical problems must be considered. The machinery manufacturer, the electrical manufacturer, and the user must arrive at common solutions for these problems as they arise. However, for all types of mills, the fundamentals of selecting the motors, the generators, and the control systems are very similar. A thorough understanding of these fundamentals will enable the prospective purchaser of a reversing cold strip mill to check the various recommendations made to him against his own particular requirements.

DISCUSSION

PRESENTED BY

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R. M. PEEPLES, Control Section, General Products Div., Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

A. MOZINA, Engineer, Control Section, General Products Div., Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

T. B. MONTGOMERY, Chief Engineer, Electrical Application Dept., Allis-Chalmers Manufacturing Co., Industrial Equipment Division, Milwaukee, Wis.

J. F. HEADLEE, Electrical Engineer, United States Steel Corp., Fairless Works, Fairless Hills, Pa. (At time of paper presentation. Now with Arthur G. McKee & Co., Cleveland, Ohio)

J. E. PEEBLES, Steel Mill Engineer, Systems Application Engineering Section, General Electric Co., Schenectady, N. Y.

FRANK W. CRAMER, Consulting Engineer, Elliott Co., Pittsburgh, Pa.

KENNETH B. FOSTER, Field Engineer, Elliott Co., Pittsburgh, Pa.

L. F. Stringer: Mr. Peebles is to be highly commended for his well organized and rather complete outline of the procedure normally followed in engineering a reversing cold mill drive.

His comments in regard to tension range and the basic limitations of the standard method of reel control whereby the armature voltage is used for maintaining a preset armature current and the motor field excitation is used for maintaining a motor counter emf directly proportional to mill speed should be carefully noted.

The use of regulating systems such as generator volt-

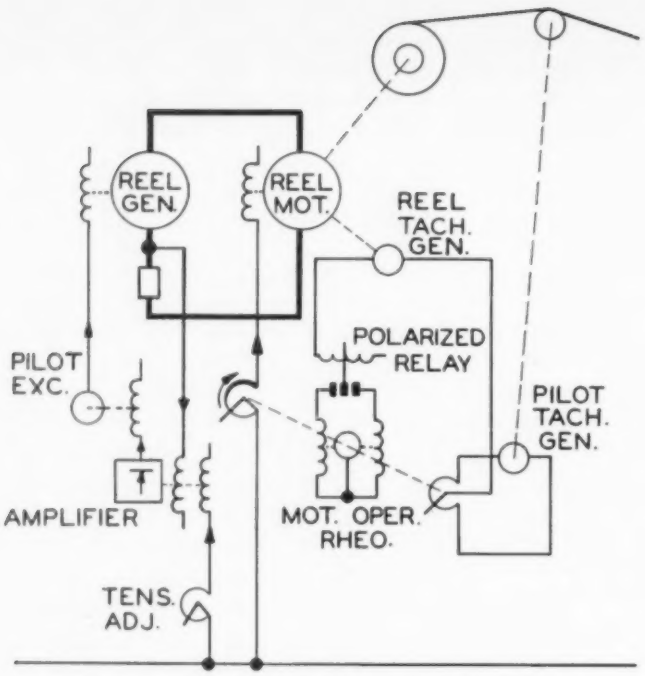

Figure 20 — Reel control for reversing mill.

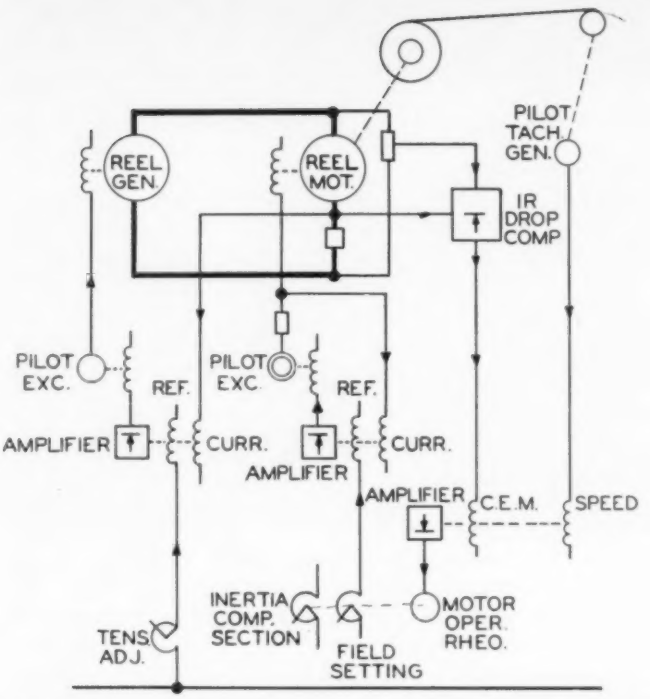

Figure 21 — In this reel control, the positioning rheostat of the roll motor regulator is driven by a magnetic amplifier.

age and in some cases motor speed regulators contributes to the effectiveness of programmed inertia compensation and the reduction of tension errors during acceleration and deceleration for this type of control.

When the tension range becomes large, however, consideration must be given to more direct means for controlling tension.

Although tensiometers require the provision of additional deflector rolls to eliminate the effect of coil build-up on tensiometer calibration, they can be used to provide a reliable and direct measure of strip tension.

The coming availability of reliable low level proportional amplifiers using transistors in the switching mode should make it possible to use wire strain gages for this purpose and simplify the mechanical arrangement.

R. M. Peeples and A. Mozina: Perhaps this discussion should be prefaced with the thought that, generally speaking, the single stand cold mill, due to the range of product, as well as physical arrangement of parts, requires a fineness of control beyond that required by most other cold mills.

Our company has for many years advocated use of systems for cold reduction mills similar to that shown by Mr. Peebles. We believe this type circuit for reeling operation is ideally suited for the reversing mill. This, we think, is true because of the fine rolling torque characteristic available, the ability to position the field and apply variable inertia compensation, and the ideal reversing and stall torque availability. We know of no other way in which these can all be obtained as neatly. The first installation which our company made of this type of reel control was made in 1939 on a single stand cold reduction mill, employing billy roll tachometers, reel current regulation by the generator and positioning equipment for the motor field. At that time, this positioning equipment was controlled by a polarized relay. This arrangement is shown in Figure 20.

This discussion is centered about the reel control as being the most critical in this type of a mill.

It was our experience that this control operated very nicely in handling the tension problem. However, the polarized relay was a source of excessive maintenance.

T. B. Montgomery: The polarized relay in Figure 20 controls the motor for the reel control rheostat. The main ring of this rheostat controls the reel motor field. Its control ring gives a measure of tachometer generator voltage which is compared with reel motor voltage, or reel generator voltage and, as Mr. Peebles has described, that gives us inertia compensation for any reel diameter.

One further thing was used in this control. There was a dial switch which allowed the operator to re-set the inertia compensation for strip widths. I believe that we found it was not used as much as the designers had expected.

The polarized relay, obviously was a source of excessive maintenance.

In the control of today, cemf is fed to a control winding of the magnetic amplifier which regulates to hold it proportional to strip speed by positioning the motor operated rheostat. The field control in this case excites a pilot exciter which in turn feeds the excitation to the reel motor.

Constant current is held by a constant current regulator of the magnetic amplifier type operating on the reel generator.

As to the range of this reel control, we feel that Mr. Peebles' statement on the range required of reel motors using a scheme such as this are a bit pessimistic.

R. M. Peeples and A. Mozina: It is also not to be denied that pilot generators driven by a strip require careful installation and maintenance. The rolls driving the pilot generators will slip, under certain conditions. They can be made to operate quite successfully, and

where the problem justifies their use, the strip driven tachometer is a fine speed reference.

Down through the years we have employed many more of these reel control circuits, along with other types, and with the advent of magnetic amplifiers, we customarily employ as our principal circuit the same one used in 1939, except that the positioning rheostat of the reel motor regulator is driven by magnetic amplifiers. This arrangement cleans up the maintenance problem and provides a smooth precise control of cemf. Figure 21 shows this arrangement.

Reel Range—We feel as though Mr. Peebles' statements on the range required of reel motors, using a scheme such as this, are a bit pessimistic. Considering the drive when speed reference is driven by the mill stand, we see no reason why the speed range of the reel motor should have to incorporate more than the range required to take care of the roll size variation, plus some consideration for regulation of the reel motor itself. If a strip driven speed reference is employed, the necessity for incorporating range to take care of the roll diameter variation disappears. With average motor design, we have found that no particular problems are encountered with a 2:1 speed range motor on a reel drive to take care of a coil build-up of 2:1. We are customarily specifying motors, for reels, in this manner at present.

Stand Drives—Under comments in relation to the main stand drive, Mr. Peebles shows an arrangement whereby the generator and the motor field are handled on one rheostat. It has been the position of our company the past several years to give the user of the equipment a choice on the manner in which this main drive is handled. It is our feeling that on an installation which is small, the scheme shown by Mr. Peebles in the paper, possibly comes out the cleanest. However, as the horsepower is increased, we prefer to recommend the use of preset fields by either a contactor arrangement or a motor operated rheostat. We obtain by this method a smoother control in that we do not have to change as much flux, since only one machine is changed during the acceleration operation. This means that regulators are not required on either the generator or motor field on the smaller drives. With a preset field arrangement, motor size can be quite large before we would specify the necessity of the current regulator on the motor field. This can be also applied to the main generators since it is not as imperative to apply regulators for obtaining good tracking with the motor operated rheostat. We also are not bothered with the increase in motor ampere load which occurs by a decrease in torque per ampere while accelerating by motor field weakening. The operator is able to adjust the mill at thread speed for the rolling load he knows he will obtain at top speed. There is then no confusion on what he might get if the speed is increased. We think this has some value. The problem of breakaway torque can be taken care of very easily by forcing the motor field from standstill. More than twenty installations of both types of main motor drives have convinced us that there is no one answer, to this aspect, which is the best in all cases.

Wide Range—As regards the control of mills which are required to roll over wide ranges, we feel that the most versatile answer at present is the tensiometer. The reel control drives can be broken up by the use of tandem motors and clutches, however, there is a limit to this attack. We have also found that the WK^2 on high power, low speed mills is not predominately in the motors themselves, therefore, there is still considerable burden placed on the electrical equipment. The handling of the low tension end of the rolling operation can only be sensed adequately, as we see it, by measuring the tension. We are at present advocating tensiometer control where the wide range is important.

T. B. Montgomery: We may add too that the holding WK^2 as low as possible to get a balanced mill reduces the job, that the control has to do, to a minimum consistent with practical economics.

J. F. Headlee: The paper describes a method of determining torque requirements for each of the reel motors and the mill motor, but does not mention how to determine the necessary reserve torques which are required for starting when excessive pressure may be applied to the mill and when lubrication film has not yet been established. How is this reserved torque determined?

The application of motor-generator sets versus rectifiers for reversing mill drives, certainly is decidedly in favor of motor-generator sets as the reversing causes back feed which can be transferred from one generator to another, whereas the back feed in the rectifier circuit must be absorbed by load resistors. Also additions of reversing contactors and associated relays, etc., creates a bad maintenance situation.

J. E. Peebles: There are several items in the discussion which deserve additional comment. Mr. Montgomery has commented on the reel speed range specified in the paper. The paper specifies 5 per cent extra range at weak field and 10 per cent extra range at base speed. It is true that many times this is more than necessary, especially when extra range is already available for such things as roll diameter compensation. However, I consider these figures the minimum which can cover all conditions. We frequently specify less range where conditions are favorable. Practical field experience shows that for smoothest installation and easiest maintenance, there should be some field range in the reel motor above that needed for coil build-up.

For the stand control, a preset motor field system is easiest to build. It has been my experience that most of the operators prefer a system of voltage increase followed by field weakening in order that they do not have to be bothered with the additional operation of presetting the motor field. In this manner, they can just accelerate until they get to the maximum current allowed them and that is all there is to it. The preset field setting may need to be changed every pass since the maximum speed with rated load varies with the pass. Most operators find less lost time at low speeds and easier control of breakaway torque when the motor field is controlled as described in the paper. Of course, the operator can have preset field control if he desires.

When the increase in motor load as the motor goes into field weakening is a bothersome problem, a current relay can be added which will stop the acceleration when the motor reaches rated current.

The paper has indicated agreement with the fact

that tensiometers will probably be recommended for wide tension ranges. However, the tensiometer adds mechanical complications and there may be many times when a good current regulator is preferable from an operators standpoint.

In Mr. Headlee's comments, he asked about the reserve torque for break-away when lubrication film has not been established. This break-away torque is a function of such variables as screw pressure and is almost impossible to calculate. The peak torque ability of the motor can be used for break-away, but economics will probably restrain a purchaser from specifying a motor with very high peak torques for just break-away.

Frank W. Cramer: The remarks by Mr. Montgomery refer to a single stand reversing mill, that was purchased about 1937, which was intended to cold roll a wide range of products from tin plate to wide sheets. It was powered by a 3500-hp motor on the main rolls and two 1750-hp motors on the reels.

When the mill was placed in operation, control difficulties arose. With narrow coils, the load on the 1750-hp reel motors at times was only 50/75 hp, while on the heavy wide coils was about full load. At this time, controls such as the rotating regulator were not available, and it required a lot of engineering ability to design a control to cover such a load range.

Mr. Montgomery practically redesigned the control on the job and put the mill in production. The mill has since been moved to another plant where it has successfully rolled many thousands of tons of product.

In the selection of main drive motors for reversing cold mills, the inertia or WK^2 of the armature is of prime consideration due to its effect on controlling the acceleration and deceleration of the mill.

During the past year the mill motor standardization committee of the AISE has completed work on three larger sizes of this line of motors and has its report approved by the Board of Directors.

These three additional frame sizes of these motors have much lower WK^2 ratings than similar motors of mill design, are more rugged, and capable of commutating heavy peak loads. The sizes and ratings of these motors are as follows:

Frame No.	Hp—230 volt 1-hr rating	Hp—460 volt 1-hr rating	Rpm
620	275	550	390
622	375	750	360
624	500	1000	340

These motors should have several advantages over existing designs and can be installed in the mill self-ventilated, if desired.

All three builders of the mill type motor have designs for these new frames and both the 620 and 622 frames have been produced. We believe there will be an expanding market for these motors, not only on main drives, but also on the large ore bridges, screw-downs, shears, and the large 500-ton ladle cranes.

T. B. Montgomery: What Mr. Cramer has brought up here is something that we normally do not discuss in an Iron and Steel meeting nor any other place.

Certainly we did not discuss it except with Mr. Cramer and those closely around him when we were up against that problem.

I think you gentlemen would be interested in what the problem really was. To give you just a little indication of it, the mill had 1750-hp reel motors with a 3:1 gear ratio and was designed to roll a range of products from heavy sheets, down to tinplate. On the finished tinplate, we were trying to hold constant tension on reels, using 1750-hp when the load was 100-hp.

I wish I could remember what the accelerating current was, but it must have been four or five times what our steady state tension load was.

These problems in early developments, it was thought, might be of interest since there was little past experience in such systems.

J. E. Peebles: I want to say one thing about the use of the mill motor. I think that is an excellent suggestion where the characteristics fit the conditions. We also will recommend for small mills, our new standard line of industrial motors which have many of the characteristics that have been specified for steel mill auxiliary motors, such as low inertia and high commutating abilities.

Kenneth B. Foster: Since we make only rotating equipment, with the exception of some very high speed electronic regulators, which we design and build, we have the advantage that we can use any control device that is on the market and can pick out the ones that we find most suitable for a given application. Our engineering people feel that the rotating regulator is a very satisfactory regulator and we wonder why you complicate them in your circuits with the magnetic amplifiers, in particular, the sixty-cycle magnetic amplifiers. We find that a sixty-cycle magnetic amplifier or a rotating regulator with sixty-cycle magnetic amplifier used as a pre-amplifier, is slower in response than the rotating regulator by itself.

Another comment that occurs to me concerns motor room ventilation. About half the mills that I know of are arranged for down-draft ventilation and the other half are up-draft. The motor room is cooler with a down-draft system, but it is more difficult to maintain brushes and commutators because they have to be under covers. So I do not know that one can say one system is better than the other. I think it is a matter of preference with the decision left to the operating people in that particular mill.

WANTED!

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Studies from research program by the AISE-RMI indicates that it may be possible to obtain a picture of the magnitude of the internal tensile stresses in rolls from the measured surface stresses.

a proposed method for calculating Residual Stresses in Iron Rolls

By CHARLES F. PECK, JR.

Associate Professor of Civil Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

▲ THIS paper presents an analytical method whereby residual internal stresses in double-poured cast iron work rolls may be calculated from measured residual surface stresses. The study is a part of a research program on fractured iron work rolls being conducted at the Carnegie Institute of Technology under the joint sponsorship of the Association of Iron and Steel Engineers and the Roll Manufacturers Institute. Previous papers (see Bibliography)[1][2][3][4][5]* have presented theoretical computations of temperature gradients and bending stresses in the rolls and the results of experimental work in the laboratory and various mills. One of the published papers[4] gave the preliminary results of measured surface strains on four rolls which were stress relieved by machining. Since that report was published, additional measurements have been made on the 18-in. roll to add to the experimental data.

The final residual strains determined by a general relaxation method and the final ring sizes of the four rolls studied are given in Table I. The corresponding residual stresses in the surface of the roll are shown in Table II.

*Numbers in parentheses denote numbers in Bibliography.

TABLE I

Final Residual Strains in Four Work Rolls — General Relaxation Method

	Strain Micro-inches per inch							
	Broken 18-in. roll		22-in. roll		18-in. roll		12-in. roll	
	Longitudinal	Tangential	Longitudinal	Tangential	Longitudinal	Tangential	Longitudinal	Tangential
	269	1302	330	885	833	1000	—35	190
	555	946	825	1020	801	900	55	190
	387	845	335	845	693	903	—45	210
	1160	1962	5	1065	713	924	0	130
	230	2302	725	1085	610	829	.....	.....
	.....	.....	340	1020	666	.....	.....	.....
	.....	.....	585	965	508	.....	.....	.....
	.....	.....	370	1055	.....	.....	.....	.....
	.....	.....	1235	.....	.....	.....	.....	.....
	.....	.....	360	.....	.....	.....	.....	.....
Total	2601	7357	5110	7940	4824	4556	—25	720
Avg.	520	1471	511	993	689	911	—6.25	180

Ring Dimensions, In.

Outside diam	18.75	22.31	19.38	12.31
Inside diam	17.88	18.31	15.38	10.69
Length	3.75	6.12	6.50	5.25

TABLE II

Surface Stresses in Compression

Roll	Longitudinal stresses, psi	Tangential stresses, psi
18 in. broken	$S_L = \frac{28.00}{1-(0.28)^2}[520+0.28\ (1471)] = 28{,}330$	$S_T = \frac{28.00}{1-(0.28)^2}[1471+0.28\ (520)] = 49{,}157$
22-in.	$S_L = \frac{23.75}{1-(0.28)^2}(511+0.28\ (993)] = 20{,}360$	$S_T = \frac{23.75}{1-(0.28)^2}[993+0.28\ (511)] = 29{,}310$
18-in.	$S_L = \frac{23.75}{1-(0.28)^2}[689+0.28\ (911)] = 24{,}300$	$S_T = \frac{23.75}{1-(0.28)^2}[911+0.28\ (689)] = 28{,}500$
12-in.	$S_L = \frac{23.75}{1-(0.28)^2}[-6.25+0.28\ (180)] = 1{,}120$	$S_T = \frac{23.75}{1-(0.28)^2}[180-0.28\ (6.25)] = 4{,}590$

COMPUTATION OF RADIAL STRESS

For the purpose of computation, the shell of the roll is considered analogous to a tank. The internal radial stress in the roll is calculated by considering it as that pressure necessary to produce a certain measured stress in the wall of the tank. A section through the roll normal to the axis is shown in Figure 1. A radial force, F_{rad}, is calculated by multiplying the unknown radial stress, S_{rad}, by the area of the diametrical plate, D′L, where D′ is taken as the diameter of the roll body without the

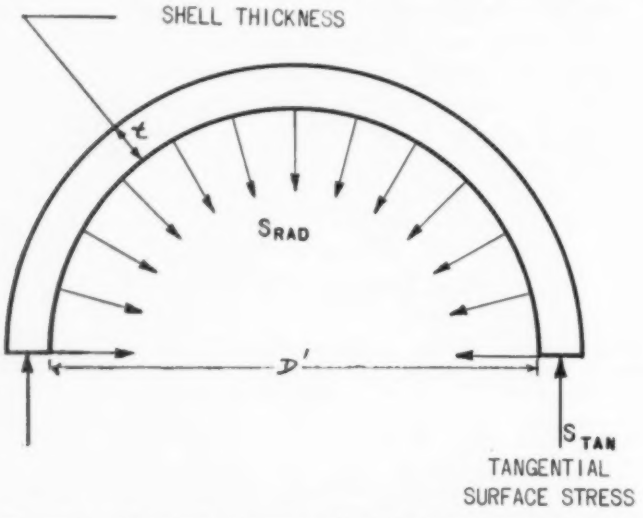


Figure 1 — Section through roll axis shows internal radial tension.

shell. The tangential force, F_{tan}, is calculated by multiplying the measured surface stress S_{tan} by the area of the diametrical shell, 2tL. By statics, the tangential force must be equal to the internal radial force; thus:

$$S_{rad} \times D'L = S_{tan} \times 2tL$$

or

$$S_{rad} = \frac{2t\ S_{tan}}{D'}$$

where a measured surface compression results in an internal radial tension and a measured surface tension results in an internal radial compression.

This expression is based upon the assumption that the shell of the roll, which has been stress relieved, is in a uniform state of stress. This assumption is based upon the work of Erler[6], who found the stress distribution in rolls using the extensive Sach's method. The results found using the tank analogy compare favorably with those found by Erler.

The resulting radial stresses for the four rolls studied are shown in Table III.

COMPUTATION OF LONGITUDINAL STRESS

Internal longitudinal stresses in the roll body are determined using the analogy of the plate shown in Figure 2. The shell of the roll was found to be in longitudinal compression. In order for this compression to exist, a tensile force must exist in the roll body and a shear force must act between the body and the shell of the roll. Figure 2 shows the position and direction of the shearing force. Again, the assumption as to the structural behavior of the roll is based on Erler's results.

A wedge-shaped portion of the roll would give a more exact analysis than the plate. However, to simplify the computational work this wedge-shaped piece was taken as a flat plate in our study. When the final distribution of stress along a radius is studied, it is apparent that the stresses near the center are small as compared to the stresses near the outside of the roll. Therefore, the error introduced by the plate analogy is minimized.

Figure 3 shows the resulting radial distribution of tensile stress along a typical radius in the roll. These

Figure 2 — Schematic shows roll section for determining internal longitudinal stresses.

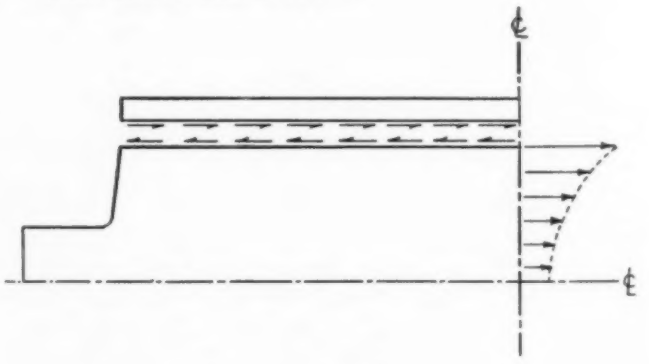


TABLE III

Internal Stresses, psi Based on 1½ in. Shell

Roll	Longitudinal stresses	Radial stresses
18-in.	$\sigma_L = 0.68 \times 28{,}330 = +19{,}250$	$\sigma_R = \frac{2 \times 1.5 \times 49{,}157}{15} = +9{,}830$
22-in.	$\sigma_L = 0.53 \times 20{,}360 = +10{,}780$	$\sigma_R = \frac{2 \times 1.5 \times 29{,}310}{19} = +4{,}630$
18-in.	$\sigma_L = 0.68 \times 24{,}300 = +16{,}500$	$\sigma_R = \frac{2 \times 1.5 \times 28{,}500}{15} = +5{,}700$
12-in.	$\sigma_L = 1.22 \times 1{,}120 = +1{,}370$	$\sigma_R = \frac{2 \times 1.5 \times 4{,}590}{9} = +1{,}530$

stresses were determined from the plate analogy of Figure 2 using the lattice solution described in an earlier paper[2]. Figure 4 shows the roll body with the shear and tensile stresses. The maximum tensile stress in the roll is calculated by equating the integrated tensile force to the compressive force in the shell of the roll.

The absolute value of the maximum tensile stress,

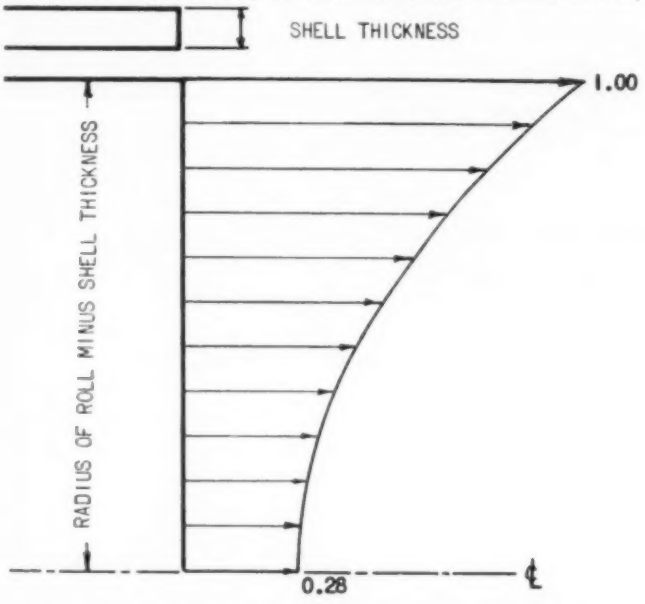
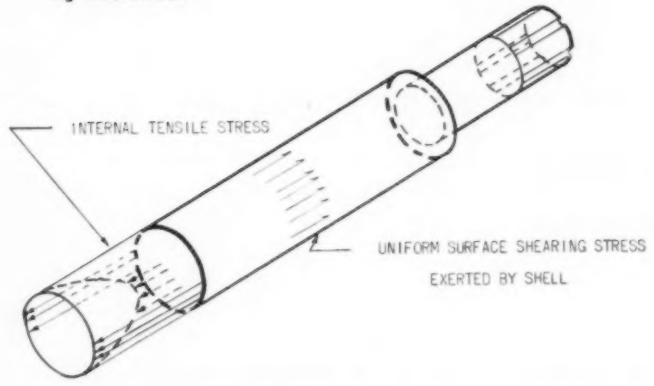


Figure 3 — Relative longitudinal stress distribution is shown in body of roll.

Figure 4 — In addition to the longitudinal stresses in the roll body there are surface shearing stresses exerted by the shell.

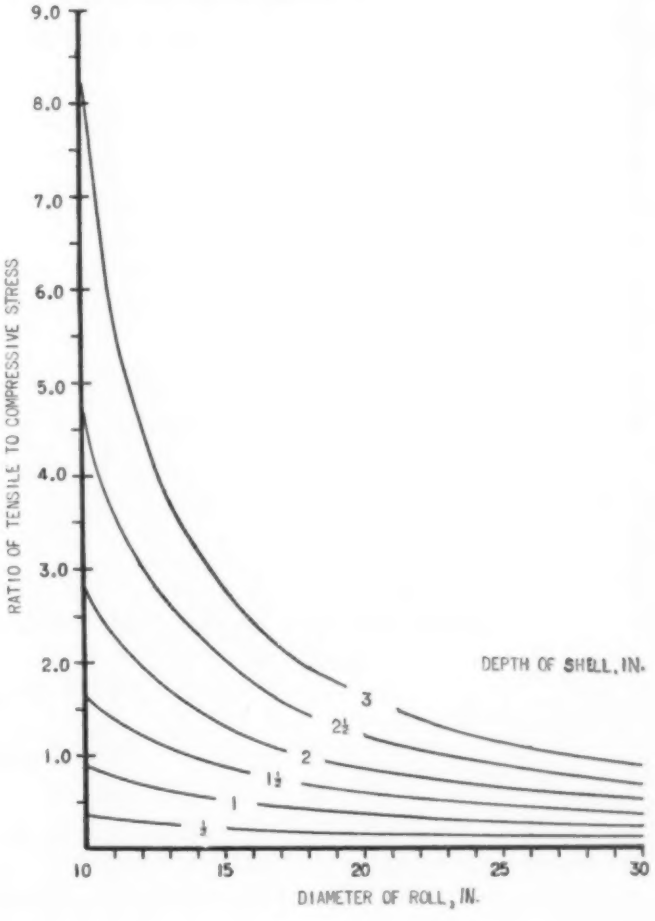


now that distribution of stress is known, is a function of:

1. The compressive stress in the shell of the roll,
2. The thickness of the shell,
3. The diameter of the roll.

For a particular roll with a given shell thickness, the ratio of the tensile to the compressive stress will be a fixed quantity and the values of this ratio for work rolls having commonly used diameters and depths of chill are shown in Figure 5. The maximum longitudinal tensile stress may be calculated for any roll, where the surface compressive stress and shell thickness are

Figure 5 — Curves give ratio of maximum longitudinal tensile stress to longitudinal compressive stress for various roll diameters.



known, by multiplying the ratio found on Figure 5 by the surface stress.

Table III shows the maximum tensile stress for the four rolls studied.

SUMMARY

It is not possible, on the basis of data collected from only four rolls, to draw any rigorous conclusions as to the amount of stress which might exist in a typical roll, or at what level the stress is excessive in a particular roll. These answers can only be gained through measurements of surface stresses on a greater number of rolls, and by a subsequent comparison of the internal stresses with service histories.

We have presented here a method by which the measured surface stresses can be translated by calculation into internal tensile stresses in rolls. These measured surface stresses were all compressive and in themselves would have caused no failures. However, failures might be caused by tensile stresses of the magnitude calculated to exist internally.

The residual surface compressive stresses may be beneficial, for they occur at locations which are generally stressed in tension during operation. However, a high compressive surface stress may be accompanied by tensile stresses in the body of the roll greater than the material can withstand.

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SOUND STEEL WITHOUT HOT TOPS at Green River Steel Corp.

By GEORGE A. DORNIN, JR.
Consulting Engineer
Warren, Ohio.

. . . . unusual good quality is obtained at Green River Steel through the use of a process which starts with a short and squatty ingot with a very heavy taper . . . . this is quickly transferred into a soaking pit, then placed in a 2500-ton upsetting press for punching and upsetting which separates the core with the segregate from the sound steel . . . . the ingot is then forged to a 16-in. square in a 1500-ton forging press . . . .

▲ IN the earliest days of steel-making it was discovered that steel (like nearly everything else in the world) shrinks on freezing. A part of this shrinkage takes the form of a decrease in physical dimensions—linear shrinkage.

In addition to this, however, there is another kind—an internal shrinkage—which steel-makers call "pipe."

The freezing of steel is accompanied by still another phenomenon known as segregation. Stated in simplest terms this is the progressive enrichment in certain elements (such as carbon, sulphur, phosphorus, manganese, etc.) throughout the ingot's freezing.

In general, the first layer to freeze (next to the mold wall) will be lowest in these elements, thus leaving the remaining liquid steel (inside this frozen shell) slightly enriched. Each successive layer will be a little richer than the one preceding it, and the very last portion to freeze, at the center of the ingot, will be richest of all.

We can (by changes in melting and pouring practice, and in shape of the ingot) exercise considerable control over the form and location of pipe and segregation. We can even, by changes in ingot size, control—to some extent—their amount or degree. But we cannot entirely eliminate either pipe or segregation, since both follow fundamental physical laws—just as inflexible as the law of gravity.

Most of the steel made today is of the type known as "open" or "rimming" steel. This is finished under an oxidizing slag (high in FeO) and the steel itself contains considerable FeO in solution.

When poured into molds, usually big-end-down, the chilling effect of the mold promotes the reaction between carbon and FeO, evolving gas bubbles (CO) which rise along the sides of the ingot and escape. After the ingot has "rimmed-in" the desired amount, an iron or steel cap is placed on it, thereby chilling and freezing its top surface.

The gas bubbles (known as "blow-holes") are trapped, and the rimming action stopped by the pressure which builds up due to the capping of the top. An almost exact analogy is the capping of a bottle of soda water. The ingot resulting from this practice has no very pronounced pipe cavity, but is, in general, a porous, spongy mass, but with a dense, soft, ductile skin. Most of the blow-holes, unless they are too near the surface, tend to weld together reasonably well on rolling—the steel always being low in carbon, and the blow holes being unoxidized.

Most of the segregation is more or less dispersed along the ingot's axis. A fairly small top crop will usually remove the most objectionable segregation as well as the area of greatest porosity, and a high yield results. The product is suitable for applications where good surface and deep drawing qualities are required, but where high strength and reliability are not. Rimmed steel is widely used to make such products as sheets for automobile bodies and home appliances, tin-plate, corrugated sheeting and the like.

When we come to such applications as aircraft, automotive and railroad axles, bearings, guns, shells, and practically all ordnance, rimmed steel is not strong enough nor reliable enough.

Here the product must be sound, dense, clean and uniform, and an entirely different technique is required. Here the internal flaws due to shrinkage and segregation must be localized and removed, instead of merely spread out as in rimmed steel.

There are three basic requirements for the production of such high-grade steels:

1. The steel must be completely de-oxidized.
2. The ingot must freeze progressively from the bottom to the top so that the pipe cavity and segregation zone will be at the extreme top end.
3. Any non-metallics present in the molten ingot must be given every possible chance to float to the top.

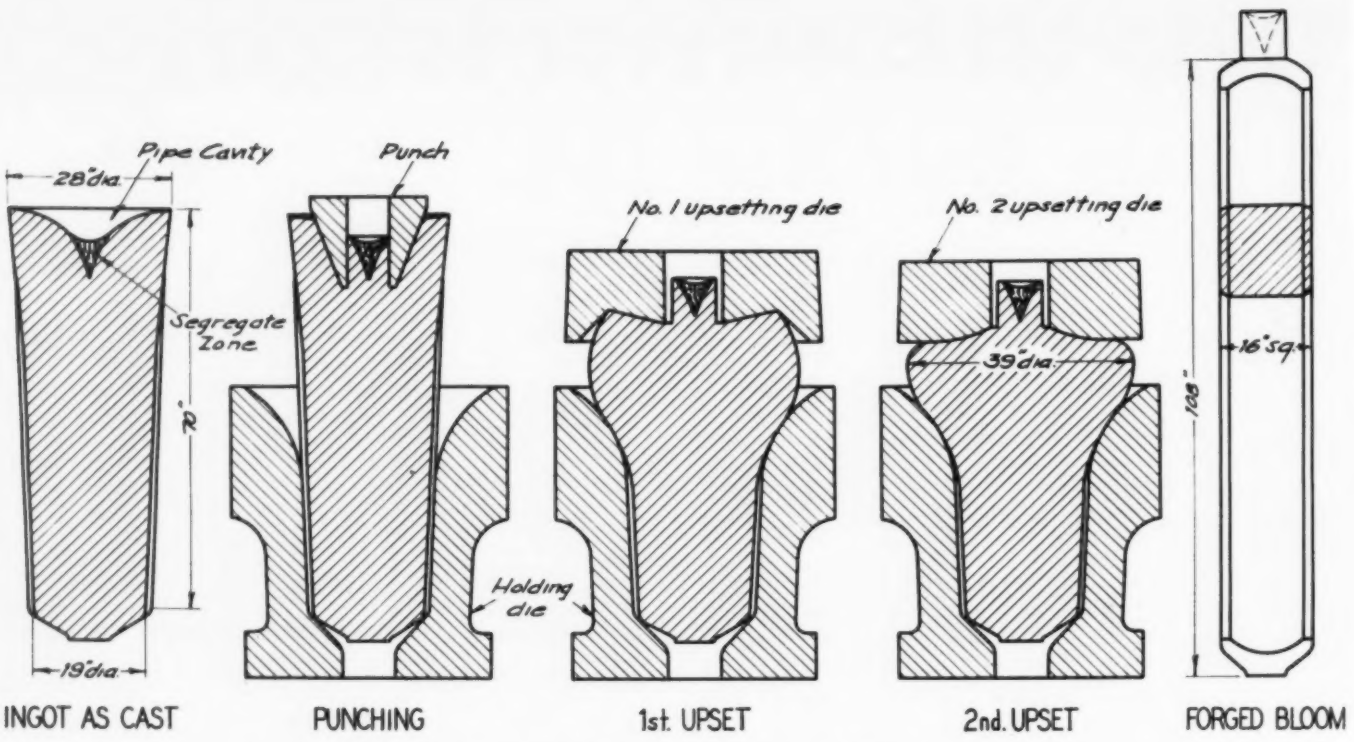


Figure 1 — Sketches show steps in processing ingots at Green River Steel Corp.

It is to this type of steel and only to this type that the process described in this paper applies.

Very early in the game, over half a century ago, steelmakers learned that a big-end-down ingot would not give the required progressive solidification from bottom to top and so today all sound steel is made in big-end-up ingots.

They also found out that the most economic way to localize the pipe and segregate was by providing at the top of the mold a refractory collar, known as a sink-head or hot-top, which, being made of insulating material, provided a liquid pool or reservoir to feed the shrinkage taking place in the main body of the ingot below it.

However, it was (and still is) necessary to provide sufficient volume in this hot-top to entirely contain the pipe cavity, and the segregate beneath it, plus sufficient reserve to take care of variations from heat to heat and ingot to ingot. This hot-top volume varies greatly depending on the type of top, and even more, on ingot size ranging all the way from as little as 7 to 8 per cent for small tool steel ingots to over 30 per cent for very large forging ingots.

However, in the ingot size range used to produce the great volume of killed steel (4,000 to 15,000 lb) the hot-top volume varies only slightly—running from about 11 to 16 per cent and averaging about 14 per cent.

The yield from fully-killed hot-top ingots, while much higher than would be obtained from the same ingots without hot-tops, is very much lower than that achieved from rimming ingots. When, to this, we add the cost of hot-tops and the bother and expense of storing, handling, breaking them off after use (or repairing and re-using them) and the nuisance that they are to the soaking pits and the mill, it is not hard to see why they are never employed unless the end use of the product makes them necessary. Steelmakers have used them only because they have had no alternative when sound steel was required.

Even from the quality standpoint they leave much to be desired. One widely used type is the inserted clay hot-top. This is a brick collar which is suspended several inches in the top of the mold. An annular space ½ to ¾ in. wide is provided between the hot-top and the mold chamber. The usual practice in pouring such ingots is to pour up to the bottom of the hot-top, wait for a seal to freeze between hot-top and mold and then pour the hot-top. Since the seal takes some time to freeze, it is nearly universal practice, when using clay tops, to pour the body of a second ingot while waiting. This practice, known as back-pouring, interferes greatly with the feeding of the ingot since, during the waiting period, the surface of the steel at the bottom of the hot-top cools off and sometimes crusts over completely. The pouring stream re-melts this crust at the center but seldom over the entire surface. Often the ingot freezes at this level before freezing is complete in the main body and, whenever this (known as "bridging") occurs, feeding stops and secondary pipe and segregation always are present in the ingot body.

An equally serious result of back-pouring (or any interruption to pouring at the hot-top juncture) is the effect on non-metallic inclusions—particularly in the lower part of the ingot.

The most nearly perfect heat of steel ever made will, by the time it gets into the molds, have picked up considerable refractory material from the furnace runner, the ladle, and the nozzle (all made or lined with brick or other refractory). In addition considerable oxidation of the molten metal must take place during tapping and pouring since these occur in air at temperatures of 2800 to 3000 F and are accompanied by violent turbulence.

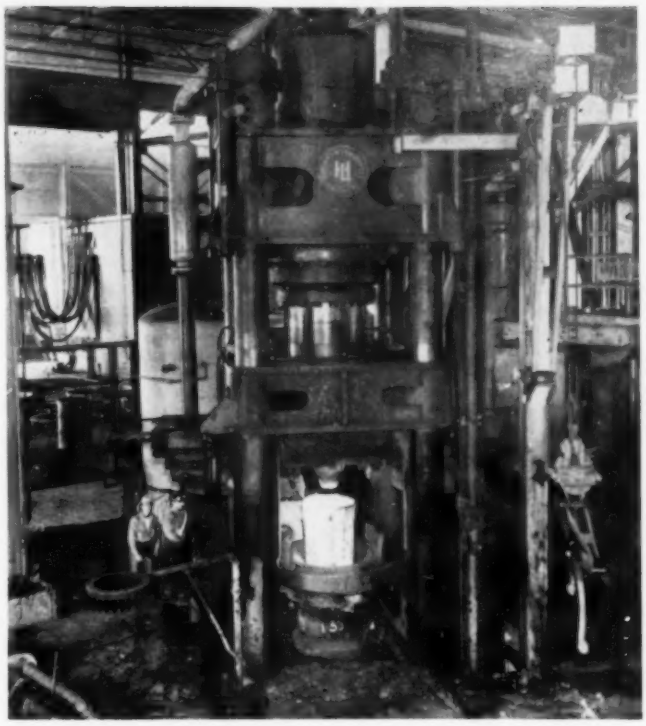


Figure 2 — The 2500-ton press is ready to start punching operations.

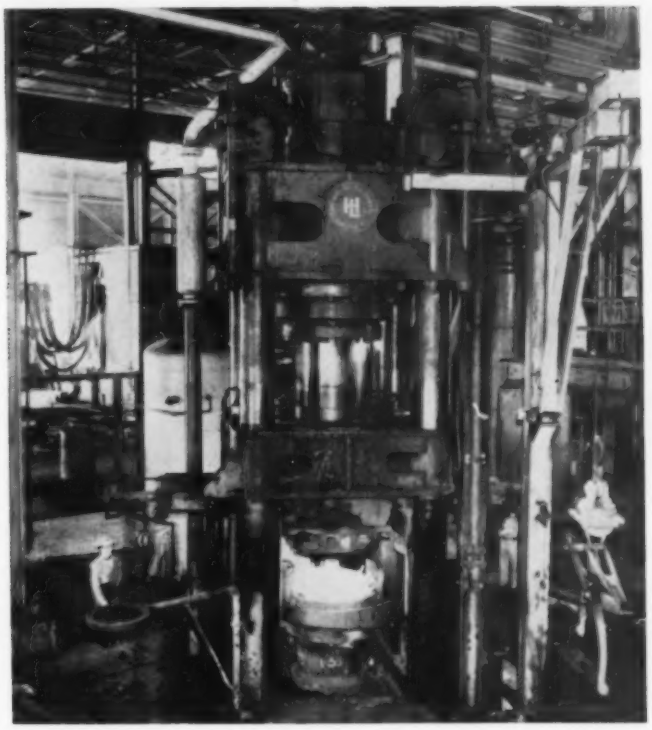


Figure 3 — Upsetting has now been completed on the 2500-ton press.

The net result is that this heat, perfect in the furnace, will be full of non-metallics by the time we get it into the molds. Fortunately, all non-metallics are lighter than steel and will, if given the chance, tend to float upward and out of the main body of the ingot.

This floating action begins as soon as the body of the ingot is poured, and the top surface becomes quite rich in them.

However, when we pour the hot-top, the force of the pouring stream drives them right back to the bottom again. Many do not float out this second time since, by now (often 2 to 3 minutes later) the steel, particularly in the lower portion, has lost much of its superheat and becomes somewhat viscous.

Now, while clay hot-tops are the only kind where back-pouring is consistently used, any hot-top necessitates a joint of some kind at the top of the mold—with the possibility of a run-out at this point. Such leaks do occur, at times, with all hot-tops and when they do it is always necessary to stop pouring until they freeze. Any interruption increases the chance of secondary pipe, segregation and non-metallics in the ingot body.

It is generally agreed by metallurgists (and rightly so) that from the standpoint of soundness and quality in general the best ingot is short and squatty with heavy taper.

Now an overwhelming percentage of the steel made today receives its initial hot-work in a m'll of some kind. Forging produces a denser structure, but rolling is very much less expensive.

Unfortunately, the best (most economical) ingot from the rolling standpoint is long and slender and has no taper at all! When we add to this fact that such long, slender ingots give higher yields than short ones, we begin to see some of the difficulties involved. Costs and quality are diametrically opposed—if you want one you must, necessarily, sacrifice the other. Obviously, a compromise is necessary, and every direct-rolled hot-top ingot represents some such compromise. The one most commonly used is too long and has too little taper for maximum soundness and yet is not long enough, and has too much taper, for minimum rolling cost.

From the foregoing, it should be fairly obvious that the hot-top ingot, even after over half a century of use, is a rather imperfect tool. My father, the late George A. Dornin, had much to do with its introduction to the American steel industry from 1915 to 1930, at which time he began the attempt to find something better.

His original aim was mainly directed at reducing costs. He wanted to eliminate the cost of using hot-tops, increase yield and reduce rolling costs, and these three things are still, today, the major economic advantages of the process.

The quality improvement (which will be dealt with later) has come as the inevitable result of the steps taken to achieve these results, and yet its value will probably prove greater, in the long run, than all other factors combined.

The experimental work which led to the process began in 1933. The tests were performed in six steel plants on a total of 22,000 tons of steel. Ingot sizes ran all the way from small models (3 in. diam) to 5,200-lb ingots. The full range of carbon steels (from 0.12 to 1.40 per cent carbon) and a wide variety of alloy grades, including "18-4-1" (18 per cent tungsten) high speed tool steel was processed. About the only grade not tried to date is stainless and plans are under way to do so soon. The first full-scale production use of the process began at the Owensboro, Kentucky plant of the Green River Steel Corporation, in January, 1954. To date some 275,000 tons of ingots have been processed in this plant.

Figure 4 — The upset ingot, upon removal from the holding die, goes to the 1500-ton press for forging.

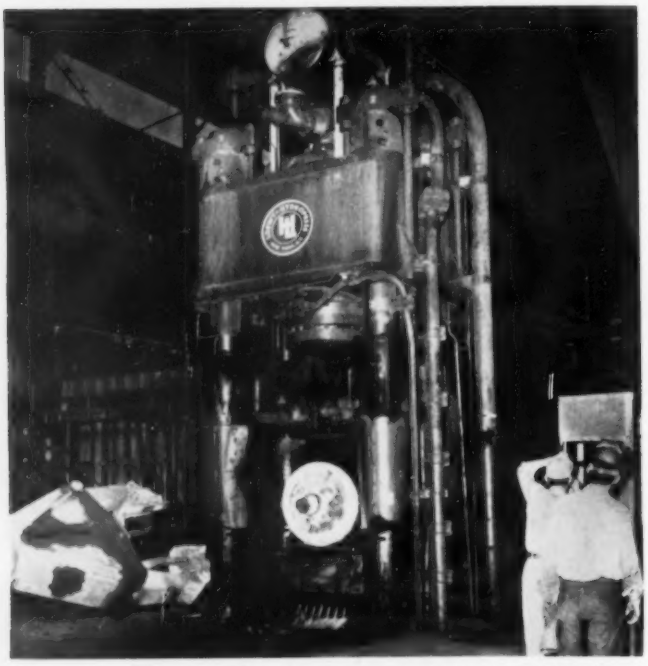


Figure 5 — The operators are now ready to forge the ingot in the 1500-ton press.

MECHANICS OF THE PROCESS

The mechanics of the process begins with the design of the ingot. Since this is not a direct-rolled ingot, considerations of rolling economy do not hamper the design and we are free to design the ingot entirely from the standpoint of maximum metallurgical quality.

Accordingly, we make it short and squatty (length over diameter—2.5) and use very heavy taper (9 in. or about 12½ per cent of body length.) This is about three times the taper normally used on hot-top ingots.

Ingots now used at Green River vary in weight from 7960 lb (3 in. down in the mold) to 7330 lb (7 in. down). The top is a smooth round, 28 in. in diam while the bottom is a 12-flute contour, 19 in. in diam across the valleys. The lower 45 in. are fluted. This blends into a smooth circular contour over a vertical distance of 12½ in., the upper 12½ in. being smooth and round.

Cork insulation, about 6 in. thick at the center and 2 in. at the outside, is applied to the ingot immediately after pouring. The ingot mold is of the plug-bottom type. Nozzles used at present are 1¼ and 1½ in. Two 60-ton top-charge electric furnaces are used for melting.

As soon as the first ingot on the heat solidifies, about 1 hr-35 min after pouring, it is loosened in the mold on a 600-ton vertical bottom-plunger stripper. While still in the mold, it is placed on a shuttle transfer car which carries it to the soaking pit building where it is charged. During transfer, the bottom of the ingot rests on a pin which pushes the top 6 to 8 in. of the ingot above the mold so the crane can get hold of it.

The entire transfer from the pouring platform to the soaking pit takes only 3 to 5 min, and, since the heat is stripped in the same order and in about the same time in which it is poured, all ingots arrive at the pits at a uniform high temperature. The ingots are vertical at all times, and all but the top few inches are protected from any sudden chill by retaining them in the molds until they are ready for charging into the soaking pit.

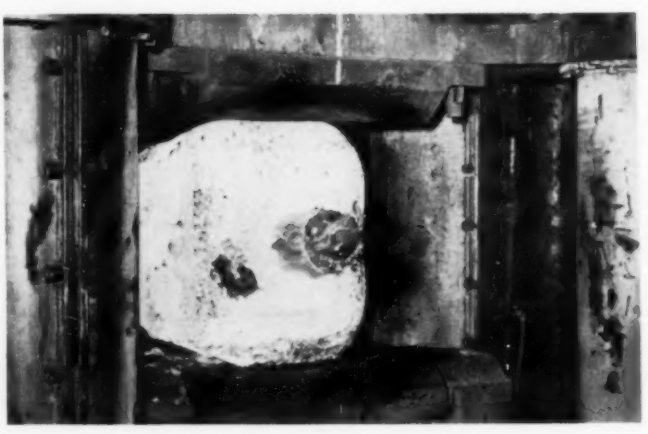
The ingots are believed to be hotter when charged than has ever been possible before on fully-killed steel. This is particularly important since the smaller the temperature range through which the ingot cools, the lower will be the stresses in cooling.

As was mentioned earlier, in a killed steel ingot, the last metal to solidify, directly under the pipe cavity, contains segregation to such a high degree that it is never usable. In this ingot, due to the very heavy taper and consequent large top area, the pipe cavity is quite shallow (about 6 in. deep) and the segregate zone is a cone-shaped mass (about 6 in. in diam and 6 in. deep) immediately beneath the pipe cavity. The primary object of the process is to isolate this segregate zone. To do so the pipe cavity is in effect turned inside out.

After the ingot is heated and soaked just as it would be for rolling, it is placed, vertically, in a cast iron holding die which is mounted on the moving bottom platen of a 2500-ton upsetting press. This platen then slides to the press center-line where a punching and two upsetting operations are performed.

First a hollow, tapered steel punch is driven into the ingot to the bottom of the segregate zone. The lower

Figure 6 — The close-up shows the forging operation about halfway complete.



cutting edges of this punch are protected by a heat-resistant weld deposit. This separates the core containing the segregate from the sound steel surrounding it. In the next step, this surrounding metal is driven down past the bottom of the core with two successive upsetting dies.

The segregate zone is now isolated but the mushroom-shaped upset ingot is not in rollable condition. Therefore, the ingot is transferred to a 1500-ton forging press where it is forged to 16-in. square by 9-ft long. During this operation, the ingot is first held at the bottom end by a manipulator while the bulged upper portion is forged from about a 39-in. diam to the finished size. It is then passed through the press to forge the lower part. This completes the process and the forged bloom then goes to the hot scarfers.

Bloom turners rotate the forging during scarfing so that all four sides can be properly conditioned. Each station has a hydraulic system for removing scarfing slag and platforms and shields for the operators.

All surface defects, including any tears that may have developed during forging, are removed by hot scarfing and the entire surface is "skinned" to remove seams. The hot forging is then recharged into the soaking pits. Here again the sound steelmaking principle of keeping the steel hot throughout its entire production cycle is applied to keep internal and external cooling stresses to a minimum.

After a flash reheat, forgings are rolled to finished size on a 24-in. two-high reversing blooming mill and a two-stand bar mill, one a three-high and the other a two-high stand. Top crop is usually taken on a shear between the bloomer and the three-high stand. The butt crop is taken on a hot-saw. Slow-cooling, inspection and final conditioning complete the cycle.

EQUIPMENT

The two presses, used in processing ingots, are water-hydraulic machines operating at 4250 psi. The hydraulic system consists, essentially, of three 5-cylinder pumps, each driven by a 500-hp motor and a pistonless air-water accumulator. The accumulator acts as a reservoir for storing high-pressure water, making it possible to use water faster, for short intervals, than the pumps can supply it.

The 2500-ton upsetting press was specially designed for this job. It has a 132-in. opening and a 78-in. stroke. The bottom slide, which carries the holding die, is actuated by two single-acting hydraulic cylinders. The punch and the two upsetting dies are mounted on slides on the upper, moving crosshead. They are moved to and from the press axis by hydraulic cylinders.

All tools center within $\frac{1}{32}$ in. A 100-ton stripper is located under the "out" position of the bottom slide to eject the upset ingot. All tool movements have push-button controls. The entire cycle (punching, upsetting and positioning three tools) takes about 1 min.

Forging is performed on a 1500-ton press with 100-in. daylight, 53-in. opening between dies, and a 48-in. stroke. Columns are on 48 by 84-in. centers. Forging dies have a front-to-back dimension of 26-in. and a 14-in. flat face. They are made of forged 4340 steel and are water-cooled.

Both presses have servo-powered operating levers and numerous safety devices to protect them against any failure in the hydraulic system. Both are of 100 per cent welded construction. Each press has its own hydraulic scale-removal system.

Transfer of the upset ingot from the 2500-ton press to the 1500-ton press is done by a jib-crane and a transfer car. As the ejector pushes the ingot upward in the holding die, it is picked up by a pair of tongs on a lift-swing jib crane. The crane swings 90 degrees and places the ingot in a cradle on a transfer car. The upset part of the ingot rests in the cradle and the bottom 2 ft projects so the ingot can be picked up by the forging manipulator.

The two manipulators are identical machines. They are track type, turret-head machines of five tons capacity each. They are quite fast to handle the great amount of turning required in this type of forging.

Now, with this description of the mechanics of the process and the equipment used, let us return to the aims and see how they are being realized after two years and 275,000 tons of production.

As mentioned earlier, the three basic aims of the process are to reduce costs by:

1. Eliminating the hot-top.
2. Increasing yield.
3. Reducing rolling cost.

In addition to these, it was hoped that we could use the process (in conjunction with hot-scarfing) to eliminate double conversion—standard practice on many alloy and all aircraft grades.

Since the presses were the last equipment to be installed at Green River, the first six months' operation was based on direct-rolling of a small hot-top ingot ($17\frac{1}{2}$-in. square—4600 lb) and we have this yardstick against which to measure results.

On this basis results have been as follows:

1. The hot-top has been eliminated.
2. The ingot-to-shipped product yield has averaged at least 13 per cent higher. The highest such

Figure 7 — Hot scarfing is the next step in the operation, and the 16 x 16-in. forging is shown at the hot-scarfing dock.

monthly yield ever obtained during the hot-top operation was 67 per cent. The product was all carbon steel. The yield for the entire year of 1955, which included considerable alloy and some aircraft steel, was about 80 per cent. The highest monthly yield obtained on plain carbon steel was 83 per cent. Note that all figures refer to ingot-to-shipped product yield since we feel that this is the only kind that really means anything. However, this means that every loss that occurs anywhere in the plant, whether from burnt steel, mill cobbles, secondary conditioning loss, or any other, is reflected in the yield.

The average rolled and shipped tonnage has increased by about 40 per cent over the best month of hot-top operation. The record month with the process was 58 per cent higher than the best hot-top month.

All grades of steel, including aircraft, have been and are regularly being single-converted.

Incidentally, the term "hot double conversion" is probably more accurate than single conversion since

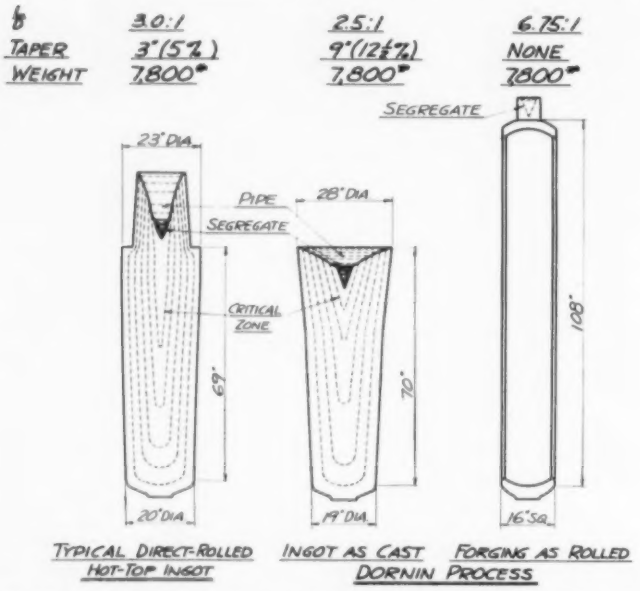


Figure 8 — Dotted lines show progressive solidification in ingots with a conventional hot top and the one obtained in this process.

the steel is heated twice in the soaking pits. It is, however, never allowed to cool completely until in final size.

Some explanation is undoubtedly in order, as regards the 40 per cent increase in mill tonnage. Prior to use of the process it was necessary to double-convert all steel through the blooming and bar mills since the plant has no other mills.

All ingots were first broken down on the bloomer, cooled, conditioned, reheated in the soaking pits and rolled (a second time on the same mill) to finished size. This meant that each ingot had to go through the mill twice and had to be heated twice—the second time being charged cold. Soaking pit congestion was further aggravated by the fact that it was necessary to divide each heat of small ingots between two pits while the present larger ingot requires only one pit per heat.

The basic fact remains, however, that when you can roll a much heavier ingot (70 per cent heavier), of smaller cross-section (16-in. against 17½-in.), at a much higher yield, your rolled tonnage is bound to increase. The long, slender forging, with no hot-top, no taper and with both ends convex for easy entrance into the mill is the ideal shape for minimum rolling cost.

Now the savings mentioned earlier are by no means achieved without some additional costs which partly off-set them.

Against the gross saving due to:

1. Elimination of the hot-top.
2. Increase in yield.
3. Reduced rolling cost.

must be subtracted:

1. The increased insulation cost (since more is required than on hot-top ingots).
2. The cost of processing.
3. The cost of reheating.

Against the saving due to single (or hot, double) conversion must be charged the cost of hot-scarfing. While exact figures cannot be quoted here, overall costs have come down drastically since the process and hot-scarfing were inaugurated. Since the principal added cost of the process is the cost of processing itself, a few words about this are in order. The operations performed on the 2500-ton press (punching and upsetting) are inherently much faster than the forging operation on the 1500-ton press. Thus production on the latter determines output of the entire installation.

Average production per month (total tonnage divided by total crew hours) runs from 21 to 24 tons per hr. Since the total operating cost of the presses is about $67 per hr, this gives a cost of about $3.00 per ton. We have every reason to expect, ultimately, to reduce this figure materially, since we have had many individual hours of 40 to 50 tons and one of 60 tons. We have even forged a number of individual ingots in 3 min each, which, done continuously, would mean 75 to 80 tons per hr.

We have recently added a third pump to increase the supply of high-pressure water since we have found that we can forge faster than two pumps can supply it.

The real bottle-neck, however, is heating. The melt shop, press shop, and mill can all handle more tonnage than the present eight pits can heat and thus any major increase in output will have to await additional heating capacity.

QUALITY

Earlier we mentioned the improvement in internal quality that has accompanied use of the process. Also, we have shown the causes for many of the internal flaws that, in the author's opinion, are inherent in conventional practice. It seems logical, then, to go through each stage, from design to finished product and see how these conditions are alleviated in all cases and entirely eliminated in many.

We start with the design of the ingot. Here the compromise between quality and cost is entirely eliminated. We design the ingot short and with the heavy taper needed to insure soundness. These proportions are also not only ideal, but actually necessary, in an ingot for processing since they result in a shallow pipe cavity and segregate zone. The processing then changes this

Figure 9 — Section shows a C-1035, 7800-lb ingot which was split as cast and etched for one hour in hot hydrochloric acid. Note dense uniform structure.

Figure 10 — View shows structure in a 15 x 15-in., 7800-lb C-1035 ingot forging after etching.

ingot into the long, slender, untapered shape ideal for rolling.

From the pouring standpoint, the ingot is not only the simplest and easiest of all ingots to pour (even simpler than rimmed and semi-killed steel) but nearly all the difficulties that arise in pouring hot top ingots—from both operating and quality standpoints—are automatically eliminated.

To begin with, the absence of the hot top removes one possible source of non-metallics—the spalling of the hot top brick. With no joint there is no possibility of seal leaks or hanger cracks resulting from them. Most important of all, there is no interruption to pouring whatever, and thus no chance to drive floating non-metallics back into the ingot. Thus we feel that there are definite reasons to expect this ingot to be sounder and cleaner than is possible with conventional practice.

It has long been recognized that forging produces a denser internal structure in steel than does rolling since forging penetrates much deeper and the pressure is applied for a longer time, whereas rolling pressure is practically instantaneous. The difference is so pronounced that often, in the making of large sections, forging will produce a satisfactory density for a given application where rolling the same ingot will not.

Of all the forms of forging, working steel between closed dies is generally admitted to give the highest degree of density. The upsetting operation very nearly approaches this, since only a small part of the upset bulge is not contained by the holding and upsetting dies. Further, the upsetting increases the area by 94 per cent and this pressure is applied along the ingot's axis, at right angles to the pressure later applied under the forging press. Much of the force of upsetting penetrates to the extreme bottom, since both the bottom of the ingot and the lower sides are deformed. The ingot at this point is fluted, while the holding die is of smooth, circular contour, and we find that the flutes are considerably flattened by the upset.

During forging on the 1500-ton press, the upset bulge (39-in. diam) is reduced to 16-in. square—a reduction of 4.7:1. The volume of the bulge, incidentally, is about 60 per cent of the ingot. This extreme reduction takes place in the very zone where secondary pipe is most common in conventional ingots.

The upsetting and forging operations work the steel in all three possible directions. About the only other applications where such work is performed on ingots is in the making of such very expensive products as die-blocks and forged steel strip mill rolls.

Now all this theory, however logical, would be entirely meaningless unless actual results could prove it out. Here the product exhibits exactly the characteristics that we would expect from the theory.

The ingot as cast is absolutely sound. We were asked by the Navy to split an ingot on a 0.35 per cent carbon heat made for them for gun tubes. They picked the ingot and we split it and we only split one. After etching for one hour in hot HCl there was absolutely no sign of secondary pipe or segregation—no flaws of any kind except, of course, the normal pipe cavity and segregation zone at the extreme top.

We also split one forged bloom (16-in. square) on the same Navy heat and this longitudinal etch showed a degree of density that is hard to believe in so large a section. Many transverse etches in 16-in., 14-in. and 12-in. sections have been made (since considerable ton-

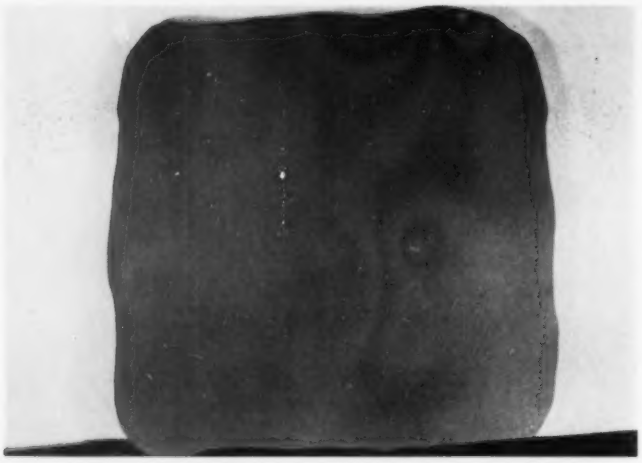


Figure 11 — Transverse top etch of C-1050 section, 16 x 16-in.

Figure 12 — Transverse bottom etch of C-1050 section, 16 x 16-in.

nage is shipped in these sizes) and they, invariably, exhibit this same density. These transverse slices have covered a wide range of grades, such as 4340, 52100, and many others.

An even more conclusive proof of over-all quality lies in some of the final applications. Here Green River is consistently meeting the most stringent specifications ever written by the aircraft industry, such as that for landing gears for jet aircraft. One such specification (the grade being 4340) calls for a transverse tensile of 260,000 to 280,000 psi with a reduction in area of 13 per cent! They are furnishing steel to this specification in sections up to 14-in. square.

Now, from the foregoing, it is pretty obvious that the author's enthusiasm for the process is of the highest order. I hope that my listeners will forgive this and realize that it is the natural result of many, many years of work on the part of my father and myself.

We should like to close by correcting any misconceptions that this enthusiasm may have created. First, the process is merely a tool. Properly used, it makes some really remarkable things possible, but there is nothing at all automatic about it—it is entirely dependent on the men who operate it. It cannot make good ingots out of bad heat—it cannot make clean ingots out of a cold, dirty heat. As far we know, it has no effect whatever on at least one serious flaw in the harder types of steel—flakes. Make a heat with this process with

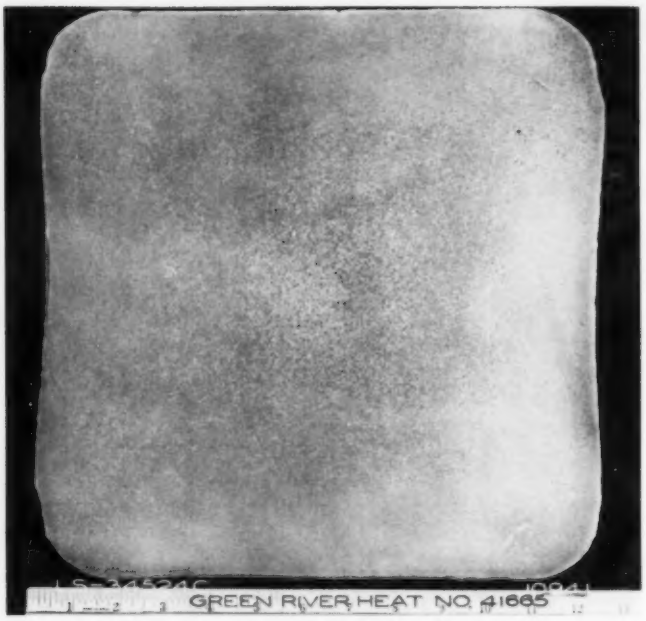


Figure 13 — Transverse middle etch of a 12 x 12-in., AISI-4340 steel. This heat was made for the landing gears of a jet aircraft requiring a transverse tensile strength of 260,000 to 280,000 psi with 13 per cent reduction in area.

high hydrogen content or cool a large section too fast and you will still have plenty of flakes. Forge an ingot with too heavy drafts (or too cold) and you will get forging breaks at the center just as you will in any other ingot.

Another thing that certainly should be mentioned is the added operating difficulties that go hand-in-hand with the addition of any operation to the production cycle. Adding the process and hot-scarfing to the normal cycle have made single conversion possible, but the operation of such a plant is not easy. Skill of the highest order is required of operating management—particularly in the matter of scheduling steel through the soaking pits.

We know quite a lot about this difficulty since the change from 100 per cent hot top practice to 100 per cent on this process was made overnight. We made the last hot top heat in January, 1954 and have never made another since. The problems, particularly at first, were difficult.

Only complete faith in the process and some unbelievably hard work on the part of the entire Green River organization have made possible the results that we are getting today.

DISCUSSION

PRESENTED BY

WILLIAM H. MEYER, Chief Metallurgist, Green River Steel Corp., Owensboro, Ky.

JACK A. KEENAN, Secretary, Green River Steel Corp., Owensboro, Ky.

William H. Meyer: I would like to elaborate briefly on a point that I consider as being most pertinent—the production of aircraft quality steels on a single (or if you prefer), a "hot-double" conversion.

We all realize that due to many variables between

a clean heat in the furnace and the solidified ingot, the expectancy of an aircraft heat meeting the necessary cleanliness requirements is considerably less than 100 per cent. This does not pose a serious economic problem—but rather one of a "nuisance" nature—in conventional plants, due to the ability of such plants to run adequate micro and/or magnetic particle tests in a re-roll billet size. Heats falling below minimum requirements are easily diverted to less stringent applications by virtue of the fact that they may be rolled into any size through a fairly wide range.

At Green River Steel, since in effect we single convert to the finished size, we were faced with the problem of either producing aircraft quality heats on a 100 per cent basis or inventorying ourselves out of business.

We are still in business and we are not carrying any distressed aircraft quality inventory.

We fully recognize the fact that there is no substitute for good melting practices, but being cognizant of the fact that poor melting in quality plants is virtually unknown today—we attribute our 99 plus per cent performance to date on aircraft quality steels to the distinctive merits of our ingot process.

Jack A. Keenan: These past two years, during which all quality steel we have produced has been by this process, probably should be considered a development period. Our operators have been learning the idiosyncrasies of the equipment—of which there are many; our operations management has been determining the areas in which improvement of both production and quality can be achieved; and our financial management has been attempting to implement such improvement. Yet, during this period—and I believe this to be quite important and a tribute to the extensive engineering performed by Mr. Dornin prior to production operations—the basic principles of the process have not changed one iota. True, we have experimented with various size ingots, various types of insulation, various finished size of forged blooms, various hot scarfing techniques—all aimed at attaining optimum conditions of production. Yet the principles of the process as detailed by the author remain today identical with those when the first heat of steel was produced in early 1954.

I would like to comment briefly on an item which Mr. Dornin mentioned, but did not pursue in detail—the ingot-to-shipped product yield. All quality steelmakers will, I believe, agree that an ingot-to-shipped product yield of 80 per cent for this type of steel is excellent. However, the full benefit of the process in so far as yield is concerned is not reflected in this figure. Several points of yield are lost in our plant due to the inadequacies of some of the equipment. When these are corrected, we feel confident that the ingot-to-shipped product yield will increase—and substantially. Perhaps an indication of percentage of top-crop will emphasize this confidence. On forging quality carbon steel, we have found we can maintain commercial requirements with a four per cent top-crop, and we are currently cropping five per cent at the top of the bloom on a production basis to allow for possible human error. Even on aircraft steel, we can maintain excellent quality with a top-crop of eight per cent.

As the author mentioned, the improvement in quality which is inherent in the process is the single feature which is foremost in our thoughts and plans. We feel that the quality of our steel is outstanding and that we are in an excellent position to satisfy the increasingly rigid specifications linked with the ever-constant search by industry for better and better materials. It is, perhaps, natural that we look to the aircraft industry as the outstanding field in which we may demonstrate the achievements of this steel.

A COKE PLANT MAINTENANCE HINT

▲ A method for preventing sticking of nozzle assemblies that supply gas for heating underjet coke batteries won a $2,000 prize for Ralph Becchia and John A. Brayton of the coke plant department at Weirton Steel. This was a record award in the Ideas for Improvement contest.

Weirton's coke batteries are fired by gas led to the combustion chamber through nozzle assemblies and regulator pipes. Stainless steel plate is welded inside the end of the regulator pipe and the plate is threaded so the nozzle assembly can be screwed into it.

The nozzle assembly consists of a replaceable ceramic burner tip which protrudes through the threaded hole in the stainless steel pipe. The assemblies are subjected to a constant temperature of 400 to 500 F, and must be removed every four or five weeks for cleaning, inspection and possible replacement of the ceramic tip so correct performance may be maintained.

During the removal process in the past, it was found that burner assemblies that had been in use for three years or more would oftentimes stick. This meant that due to heat and wear, the threads on the nozzle assembly had become "welded" or "frozen" to the threads in the plate at the end of the regulator pipe.

When this occurred, the burner either had to be taken out of service which resulted in the improper distribution of heat in the coke battery, or specially-designed equipment had to be used to forcibly remove the regulator pipe with the stuck burner assembly.

The new idea consists of using a single, coarse square thread on the nozzle assembly which previously had 8 standard pipe threads per in. on the section that screwed into the steel plate on the regulator pipe. This permits the nozzle assembly to be installed and removed with one turn. The testing period of one year has shown that the modified nozzle assembly can be easily removed for cleaning and inspection, and the problems of sticking have been eliminated thus reducing maintenance cost. The new design is being installed in the new coke battery under construction and in existing units as the assemblies require changing.

CURRENT AISE DISTRICT SECTION MEETING NOTICES

BIRMINGHAM SECTION

Monday, January 28, 1957 — Dinner 6:30 P.M., Meeting 8:00 P.M.

"The Development in Quality Control in Steelmaking from the Open Hearth to the Blooming Mills," by R. B. Gibson, Secretary and Treasurer, Southeastern Products Corp., Birmingham, Ala.

Thomas Jefferson Hotel, Birmingham, Ala.

BUFFALO SECTION

Tuesday, January 8, 1957 — Dinner 6:30 P.M., Meeting 8:00 P.M.

"Recent Application of Hydraulics to Steel Mill Drives," by Charles P. Taylor, Manager Sales Engineering, Berry Division, Oliver Iron and Steel Corp., Pittsburgh, Pa.

Hotel Sheraton, 715 Delaware Avenue, Buffalo, N. Y.

CHICAGO SECTION

Wednesday, January 9, 1957 — Dinner 6:30 P.M., Meeting 7:30 P.M.

"Economic Impact of the St. Lawrence Waterway Development on Chicago Basic Industry," by Maxim M. Cohen, General Manager, Chicago Regional Port District.

Phil Smidt's Restaurant, 1205 North Calumet Avenue, Hammond, Ind.

CLEVELAND SECTION

Tuesday, January 15, 1957 — Dinner 6:30 P.M., Meeting 8:00 P.M.

Inspection Trip — Eastlake Plant

"The Coal Pipe Lines," by C. A. Dauber, Director of Civil and Mechanical Engineering, the Cleveland Illuminating Co., Cleveland, Ohio.

The University Club, 3813 Euclid Avenue, Cleveland, Ohio

DETROIT SECTION

Tuesday, January 8, 1957 — Dinner 6:30 P.M., Meeting 8:00 P.M.

Ford Steel Division Night.

"Accent on Maintenance," by H. F. McCullough, General Manager, Service Shop Dept., General Electric Co., Schenectady, N. Y.

Information Please Panel on **"Everyday Maintenance Problems,"** discussed by Detroit Area Steel Mill Personnel.

Dinner and Meeting

Meridian Room, Dearborn Engineering Laboratories

LOS ANGELES SECTION

Data not available.

PHILADELPHIA SECTION

Saturday, January 5, 1957 — Dinner 6:00 P.M. Meeting 7:00 P.M.

Old Timer's Night

"Engineering as Applied by the Mayas in 400 A.D.," by L. V. Black, Superintendent Electrical Department, Bethlehem Steel Co., Bethlehem, Pa.

"Equipment, Installation and Economics of Air-Conditioning Existing Buildings," by F. Robert Dougherty, Engineering Department, Lukens Steel Co., Coatesville, Pa.

"Operation of the Power System at Fairless Works," by George A. Goetz, General Foreman, Electrical Operations, United States Steel Corp., Fairless Works, Fairless Hills, Pa.

Engineers' Club, 1317 Spruce Street, Philadelphia, Pa.

PITTSBURGH SECTION

Monday, January 14, 1957 — Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Establishing and Applying Maintenance Incentives," by R. B. Hewitt, Company Industrial Engineer, Crucible Steel Company of America, Pittsburgh, Pa.

University Club, University Place, Pittsburgh, Pa.

ST. LOUIS SECTION

Wednesday January 30, 1957 —
Social Hour 6:00 P.M.
Dinner 7:00 P.M., Meeting 8:00 P.M.,

"Industrial Waste and Stream Pollution," by C. W. Klassen, Chief Engineer, Department of Public Health, State of Illinois, Springfield, Ill.

Elks Club, Granite City, Ill.

SAN FRANCISCO SECTION

Tuesday, January 15, 1957 — Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

Bethlehem Pacific Coast Steel Corp. Night.

"Some Aspects of Research in the Steel Industry," by Paul Ffield, Assistant Manager, Research Department, Bethlehem Steel Co., Bethlehem, Pa.

Shattuck Hotel, Durant and Shattuck Streets, Berkeley, Calif.

UTAH SECTION

Monday, January 14, 1957 — Social Hour 6:30 P.M., Dinner 7:30 P.M., Meeting 8:30 P.M.

"Iron Ore and Blast Furnace Operations."

Skyliner Cafe, Provo, Utah

YOUNGSTOWN SECTION

Monday, January 28, 1957 — Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Television Transmission," by R. C. Clark, Supervisor, Public Relations Department, the Ohio Bell Telephone Co., Cleveland, Ohio.

Mahoning Country Club, Girard, Ohio

Raw Material Inventory Through PHOTOGRAMMETRY

By ROBERT A. CUMMINGS, JR.
Robert A. Cummings, Jr. Associates
Pittsburgh, Pa.

. . . . accurate surveys of raw material piles can be obtained from photogrammetry . . . . simultaneous data may be obtained for large areas . . . . two-foot contours can easily be obtained on a 50-ft-to-the-in. map . . . .

▲ TO the engineer and accountant, raw material inventory has always presented a difficult problem for accuracy. Irregularities, both in height and in horizontal dimensions modify absolute calculations for volume, which in turn involve variables in density and unit values. Low cost materials, such as sand and gravel, require less time for detail calculations than coal or iron ore. The total value is less affected in the sum total through cheaper unit values.

The ideal stockpile should be a cube, or a geometric shape having uniform dimensions. The calculations in such a case are simple and precise. However, stockpiles are generally irregular, particularly in vertical cross-section. In the case of pyramids, the volume is calculated on a basis of using a third of the height, whereas in the case of a cube having varying heights, the volume is calculated on the average height basis. These considerations must be applied correctly in volumetric calculations and measured consistently in the field, where averages may be within confined walls, such as, under craneways. The slope of the sides usually takes a position as the angle of repose of the material.

The methods used in securing the volumes of stockpiles have been as follows:

1. The observation method.
2. The field survey method.
3. Photogrammetry, using aerial photography, field control and third dimensional compilation.

The first method, observation, is the practice of experienced men, individually or collectively, in viewing the stockpile, and by judgment, making a good guess of both the volume and tonnage of the material stored. This method is not accurate and usually produces serious errors in value in a company's financial statement; usually an overage develops that must be adjusted at a later date when the stockpile is empty.

The second method is the use of a field survey party in taking measurements around the storage area, and determining distances vertically at uniform distances apart or at sharp breaks in the different cross-sections. Field measurements with a level, transit, rodman and chainman, necessitate walking over the storage pile to determine the proper elevations. The resulting accuracy of the compilation is dependent upon the selection of the proper rod reading points, and the notation of sharp breaks in the vertical and the horizontal. The cross-sections are spaced 20 or 25 ft apart, depending upon the uniformity or otherwise of the stockpile.

The calculations then become routine by finding the area in each section and multiplying these sections by the longitudinal distance between the sections by prismoidal formula. The stockpile volume is the summation of each of the separate sections previously calculated. The accuracy of this method is dependent strictly upon the skillful selection of the high and low points in the field, and unless this work is done carefully, serious errors in the volume will result.

A field method, sometimes used by management at steel plants where iron ore is stored under a craneway, is the measurement of the distance from top of stockpile to bottom of cranebridge, by using a weighted chain.

Calculations of volume have been determined also by averaging out depths of the pile upon a close grid system. This method presumes that the stockpile is a series of columns throughout, and the average heights are equivalent to an average depth of the pile. This is fairly satisfactory when the stockpile is somewhat uniform—but when the pile is loosely placed, the results are incorrect.

The third method is the volumetric determination by means of photogrammetry. The first step on such a project is the taking of duplicate aerial photographs from two different positions of the stockpile at a predetermined low altitude. The photography should be performed with a precision aerial cartographic camera that has been calibrated by the U. S. Bureau of Standards for the critical accuracy required. The day, and

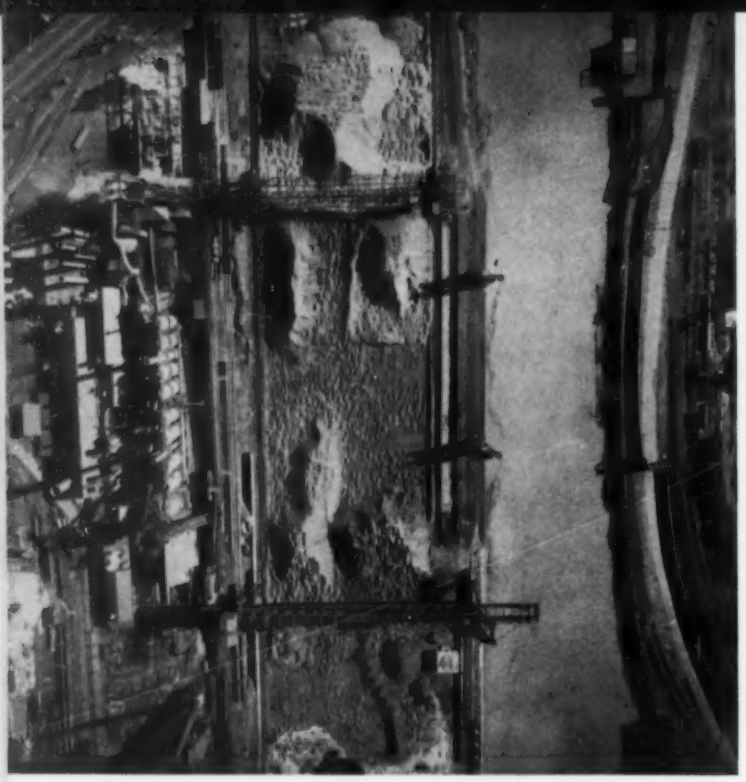


Figure 1 — Good camera work on the part of the aerial photographer can result in remarkable detail on the final photograph. Flight line was from the bottom to the top of the photograph.

Figure 2 — This is the next picture taken after that in Figure 1. An overlap of about 55 per cent is used.

the time of day of the photography is important, because this information is needed to adjust plant records to the inventory findings on the day photographed.

It is desirable to arrange the photgraphing as near mid-day as possible to avoid unnecessary shadows which may impair the plotting accuracy of the compilation. Furthermore, the flight height of the aircraft should not be too low to prevent blind spots on the stereoscopic photography due to vertical slopes of the stockpile. Such a situation becomes serious when the angle of repose of the raw material exceeds 45 degrees. The photography will be then shown only on one side which will prevent any stereo-compilation. Best results on compiling coal, or on ore or limestone stockpiles is a specification of map at scale of two-ft contour on a 50-ft to the in. map, using an 8¼-in. focal length camera at a flight height of 1650 ft.

The accuracy of the compilation is quite dependent upon the flight height of the photography. Doubling the flight height could produce five-ft contours with 200 ft to the in. map, but the accuracy would be lessened by as much as a 5 per cent error as has been demonstrated by actual comparison.

The quality of the photography is very important, particularly when the picture does not present a true stereoscopic appearance. A slow speed shutter may show movement or blur if the aircraft is moving too fast. The photographic image must be sharp and distinct. Proper photographic exposure must be adjusted for color of the stockpile. Light color materials such as limestone and sulphur would be overexposed if taken with the same camera stop opening as that taken with coal or iron ore. Separate flights may be required where these different colored materials appear adjacent to each other, so that different exposures may be used. Hallations from over-exposure prevents compilation, whereas under-exposure may be an advantage.

The aircraft used in such flights usually is a single engine plane, such as a Cessna 170-B. Slow speeds are advantageous for good photography, and the practice of experienced pilots is to fly into the wind with flaps down to secure a flight speed of 50 to 60 mph. Further consideration must be given to handling aircraft at low altitudes in encountering turbulent air current and maintaining a level photograph in a split-second timing, and in securing two photographs of the same stockpile from two different positions. Updrafts from blast furnaces cause some difficulty in maintaining the plane level. A further requirement in these operations, is the maintenance of proper vacuum on the camera with gusty air currents. Improper vacuum in the camera will produce a warped film at the time of exposure, and thereby not permit the normal accuracy of one foot on the specifications of a two-ft contour map. The overlap area of each photograph must be 55 per cent of the preceding one. After the film has been processed, positive plates, called diapositives, are printed and then placed in the stereo-plotter for compilation. The scale of the map is predetermined and is compared and set to a distance measurement of recognizable points on the photography. This information data is usually available in the engineering department of the plant, as well as four points of elevations. Points or distances on a retaining wall or craneway would be satisfactory, if available. Otherwise, this information must be secured by a field survey party, using recognizable picture points for the necessary horizontal and vertical control to adjust the projected aerial photograph to a level plane, and maintain a predetermined fixed mapping scale—which is four times the flown photography.

The projection of the photography, when viewed through red and blue glasses, appears in third dimension in an accurately scaled and level picture on the drawing table. Compilation is made by using a fine dot of light as a measuring target for horizontal distances, and the same target for levels in determining each of

TABLE I
Approximate Weight of Raw Materials

Bulk material	Lb per cubic foot in place	Per cent swell	Swell factor	Loose weight per cu ft
Ashes, hard coal	26 to 37	8	0.93	24 to 34
soft coal, with clinkers	37 to 56	8	0.93	34 to 52
soft coal, ordinary	40 to 45	8	0.93	37 to 42
Bauxite	100 to 160	33	0.75	100 to 120
Brick	.....	.....	.....	100
Brick bats	.....	.....	.....	55
Cement, Portland	110	20	0.83	91
Coal, Anthracite	56	.....	.....	.....
Bituminous, run of mine	.....	.....	.....	55
Bituminous, slack piled	.....	.....	.....	50
Coke, Lump, loose	.....	.....	.....	23 to 32
Solvay, egg	.....	.....	.....	31
Gas, egg	.....	.....	.....	29
Gas, furnace	.....	.....	.....	27
Copper, ore	140	35	0.74	104
Dolomite, crushed fine	.....	.....	.....	95
Broken lump	.....	.....	.....	95
Gypsum, crushed to 3 in.	.....	.....	.....	95
Calcined	.....	.....	.....	60
Iron ore	.....	.....	.....	.....
Hematite	241 to 322	.....	0.45	144
Limonite	237	.....	.....	.....
Magnetite	315	.....	.....	.....
Kaolin	104	30	0.77	80
Lead ore	465	.....	.....	.....
Lime	.....	.....	.....	52
Limestone, blasted	156	67-75	0.60-0.57	89 to 93
Loose, crushed	.....	.....	.....	96 to 100
Marble	170	67-75	0.60-0.57	97 to 102
Phosphate rock	200	.....	.....	.....
Slag, sand	62	12	0.89	55
Solid	160 to 180	33	0.75	98 to 120
Crushed	.....	.....	.....	70
Furnace, granulated	59	12	0.89	53
Slate	170 to 180	30	0.77	130 to 139
Trap rock	188	50	0.67	126

the succeeding contour lines. This is a precision instrument and corresponds in importance to a field transit in determining distances and elevations from the master controlling data used in setting up the projected photography.

It must be understood that only visible data can be plotted and measured. This is particularly true in the case of stockpiles that have settled due to the excessive weight on an unstable bottom. Settled stockpiles are frequent when surcharged on a walled storage area or pier, where the supporting bottom is excessively compressed. The ore so hidden from the photography must be probed in the field by accurate interior measurements. The accuracy of the compilations is usually warranted correct within half a contour distance. When the photography is flown for two-ft contour specifications, it is accurate within one ft. When the stockpile is very irregular, small projections and depressions frequently appear within the contour limits. These variations are usually disregarded when these irregularities fall within the contour limits, but frequently the projections and depressions occur within the limits of several contours. These should be marked clearly so that if the area is quite substantial, corrections can be made in the calculations.

The next step is the determination of the areas within the contour lines. This is usually performed by using a planimeter with a conversion factor for the area in square feet. This step is precise and time consuming and investigations are now being studied for simplification by electronic computations to attain speed with accuracy.

The volume of the entire stockpile is the summation of the individual horizontal layers that lie between the measured contoured areas. Deductions and additions for the depressed and projected areas are corrections to be made in the final adjustment.

The determination of tonnage requires full consideration of the raw material as it is presently stored in the stockpile. It may be just recently stored or lie in place for considerable time. Such conditions present several correcting factors, particularly swelling and shrinkage, and the percentage of voids.

The unit of weight used is the density of the raw material in an unmined state. The volume of the stockpile then should be converted to an equivalent volume in the original unmined state. A suitable swell factor should be applied, taking into consideration whether the ore is lump or fine ore, and the correct unit used for the per cent void suitable. An example of swell of hard rock may be 50 per cent of its original volume, or it may be 35 per cent for crushed rock. Table I is typical of some raw materials.

Each plant has information on the characteristics of his own raw material. These should be compared season to season and corrected for the length of time in the storage, as the material returns to its compacted condition of its unmined state. The above information is given as a guide but the specific conversion factors must be reviewed with each particular operation.

Photogrammetry is, therefore, a modern up-to-date and accurate method of determining volumes of raw materials.

RAW MATERIAL INVENTORY OF COAL

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. . . . several problems difficult to overcome in taking inventories of raw materials are errors introduced because of various densities in storage piles due to packing, etc., and errors introduced because the contour of the bottom of the pile may not be known due to foundation settlement and subsidence . . . .

▲ THE raw material inventory of coal is an extremely broad subject, and literally volumes have been written concerning it. This paper will discuss the use of photogrammetry in raw material inventory, particularly stock pile inventory from the experience of the Tennessee Valley Authority, and will also discuss briefly two other important problems of inventory.

The Tennessee Valley Authority has utilized photogrammetry as one of several methods of inventory for several years. Choice of the method for a particular stock pile is dependent on the circumstances involved. The probable accuracy and the relative economy of the photogrammetric method are definite advantages. But regardless of whether it is more accurate or less expensive, there are several other advantages of interest.

In 1949 construction was started on the Johnsonville steam plant on Kentucky Lake and in anticipation of its first commercial operation in October 1951, a rather large volume of coal had been placed in storage on a newly constructed coal storage yard—or rather—coal storage area. Since that time, six additional plants at strategic points in the Tennessee Valley have been constructed and have their own similar stock piles of coal. These steam plants are "large" to say the least (Kingston with 1,600,000 kw is presently the largest steam electric generating plant in the world), and correspondingly their reserve coal supplies are quite large. These stock piles average from 30 to 40 acres in area, around 30 ft in height, and will individually contain some 600,000 or more tons of coal.

It is estimated that the steam plants either now in operation or under construction, will consume approximately 18,000,000 tons of coal per year. Customarily the storage areas will contain approximately three months supply, representing some 4,000,000 to 5,000,000 tons of coal in storage at any one time. This is in seven very large piles and three smaller ones.

These figures are mentioned only to give some impression of the magnitude of the inventory problem which confronts us. In January 1951, TVA began consideration of stock pile inventory by photogrammetric methods. We were prompted by an article which reported success with the method. TVA has utilized photogrammetry in its topographic mapping program since 1935, consequently stereo-photogrammetric equipment, airplanes, cameras and trained personnel were available. In March 1951, we accomplished our first inventory by photogrammetry at one of the comparatively small steam plants which had been in operation for several years. The results were gratifying and to varying degree, photogrammetric inventories have been used since.

As has been stated, there are several methods of determining the volume of an outdoor stock pile. The shape of the pile, its location, the availability of surveying personnel and photogrammetric equipment, are all factors which bear on the choice of method. The photogrammetric method is particularly adaptable where several large permanently located stock piles are relatively widely scattered. Then there are, of course, circumstances where plane table methods will prove just as satisfactory and economical if they include instances where survey parties are readily available and where the stock piles are smoothed off and regularly shaped.

Generally the photogrammetric method is more accurate and some less expensive, if proper conditions exist. But obviously to tie up an expensive airplane and the photogrammetric equipment necessary in subsequent operations to compute the volume of a small isolated stock pile would be like employing a steam shovel to plant a rose bush. However, if the photography of several stock piles can be combined into one mission, the economic balance swings in the opposite direction. In addition to the economy, there are several other advantages in the photogrammetric approach to inventory by large organizations. Photographing all of the material owned by one organization on the same date enables that organization to adopt a common inventory date, regardless of when the remaining compilation and computations may be accomplished, i.e., the shape of the piles at a given instant is recorded on film, and is available for compilation into topographic maps at any desired time thereafter. A common inventory date reduces the bookkeeping problem that exists if one must wait for results over a period of days or weeks from one or two survey parties going from stock pile location to stock pile location. The photograph becomes a record of conditions as they existed at the time of photography, and the resulting inventory can be

duplicated or checked even by other individuals years later, should any question arise, or if it otherwise becomes desirable to do so.

By recording the time the plane passes over a given stock pile and by correlating this time with the records of receipt and use of coal during inventory, normal operations on the pile do not have to be shut down for the duration of the conventional field survey.

In TVA, in addition to coal, there are several different raw materials in connection with the chemical and fertilizer industries which must be inventoried. Most of these outdoor piles are photographed on the same day as the coal, and also inventoried with photogrammetry, but this paper will be confined to the large outdoor coal stock piles.

The coal stock piles at the large steam plants represent a specific type of pile, as it affects the problems of inventory. They are plateau like in shape and are built in layers, in a sense. In all of these piles, the coal has been crushed so that it will pass through a 1¼-in. screen and the coal is stock piled by means of both rubber-tired and crawler-type tractors hauling rubber-tired scrapers. Operators are instructed to spread the coal in as thin a layer as practicable, and to accomplish compaction of the coal pile by successive passages of tractors and scrapers over the newly deposited coal. The coal involved is bituminous and under these stocking methods, it is surprising how completely the voids are filled with fines and how nearly the coal piles so built resemble coal in its solid state, even to the point of glistening in the sun in the wake of a bulldozer being used to reclaim the coal.

The reason for and intended use of the inventory of raw materials varies from organizations to organization and may alter the accuracy required. It is my understanding that one use of raw material inventories of ore, in the Pittsburgh area, is to determine whether sufficient quantities exist to carry beyond the spring thaws. This is of course in addition to the need for normal fiscal inventories.

The Tennessee Valley Authority being a government owned corporation is very closely accountable to the General Accounting Office. Also, certain of the rate structures vary with the cost of power production. In view of these two factors, extreme accuracy is demanded.

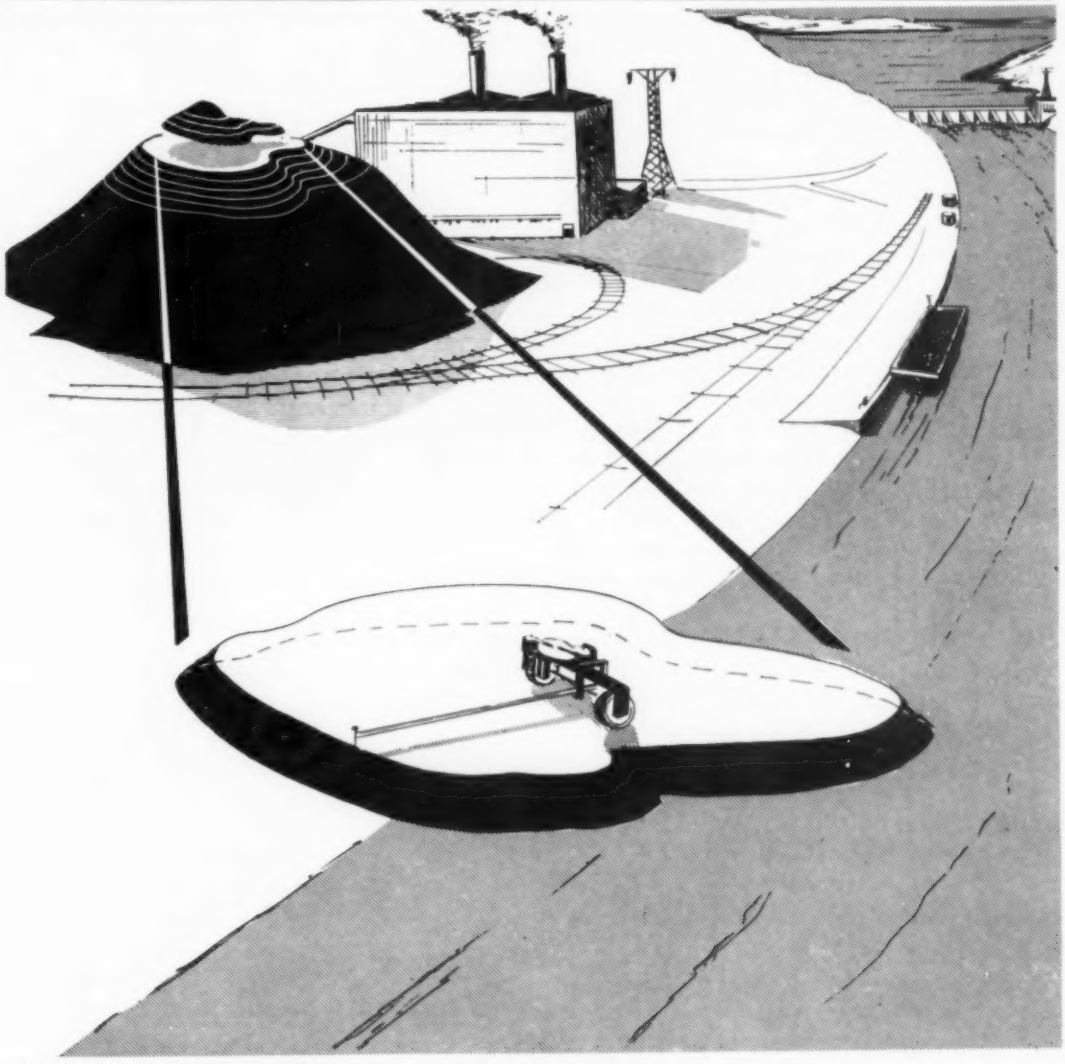

Figure 1 — Method of computing volume by planimetering contours is indicated by the sketch.

It has been our experience that the outside shape of the larger piles can be determined and duplicated by photogrammetric methods within an accuracy that will affect volume only some 3 to 5 per cent.

This accuracy is a direct function of the contour interval used, and the flying height adopted. So, whereas, the accuracy of the elevation and the configuration of the topographic map, of the top of two piles of different height, but covering the same area, might be identical, the percentage of error of volume would vary considerably. The higher the pile, the greater the probable accuracy in the plateau-like stock pile.

Over 30 acres, 0.2 ft represents approximately 8,000 tons of coal.

We have an interesting comparison of relative accuracy of inventory methods from our experimental days. In the chemical storage pile area, there was a washed sand pile in which there was no activity either in or out for several years. This pile was inventoried by three different methods in three successive years, with the following results:

Year	Method	Results, tons	Per cent difference between plane table method	Per cent difference between cross section method
1950	Cross sectioned	26,148	2.9	.....
1951	Plane table	25,405	.....	2.7
1952	Aerial survey	26,098	2.7	0.2

The widest variance is 2.9 per cent between the plane table and cross-section method and the smallest is 0.2 per cent between the aerial survey and cross-section method. There are also two other problems in inventory, the solution to which is possibly even more elusive. Modern stocking and reclaiming methods practically require that the base of large piles be a plane with only sufficient slope for drainage. To develop such an area in the type terrain of most steam plants requires grading, usually both cut and fill.

Storage areas are constructed to definite plans and grades and even detailed surveys made of them after completion.

But what happens to these areas, particularly the fill areas, when a small mountain of a half-million or more tons of coal is built on top of it?

And at the time of inventory, with the coal there, how do you determine the shape of the bottom of the pile, and what effect does distortion of this base have on volume?

We know that the average storage yard base may depress under certain conditions up to a foot or more, under the weight of several feet of coal, and it may rebound some when coal is removed.

The importance of the effect of this condition is being recognized more and more with experience. You can readily see that 20,000 to 30,000 tons of coal might in effect "hide" underneath such a pile, if only the theoretical base contours are used.

So it becomes imperative to know something of the bottom of the pile at the time of inventory.

In the more recently established fuel piles, 6 x 6 ft concrete slabs have been placed at selected and coordinated points and accurate elevations determined of them prior to the building of the pile. Settlement can then be checked by probing through the coal to the slab.

Recently it has been determined that ¼-in. steel plates laid on top of the ground serve better than the concrete slabs. The steel will likely deteriorate through chemical action over a period of years, but they should last long enough to establish an adequate map of the base in its probable permanent position.

The importance of this problem on inventory accuracy cannot be stressed too much. Nor can the need for careful planning and site preparation of the storage yard. For the more valuable ores, one might be justified in constructing a rigid paved base.

Take the case of a conical or pyramid shaped pile. An error of 0.2 ft or 0.3 ft in elevation of the base can be more serious than 2 or 3-ft error in the height of the pile.

In inventorying a very shallow pile over a large area and not knowing whether permanent or temporary subsidence has taken place, we find it becomes necessary to dig through to base contact and actually measure coal thickness.

It is planned after the yards have been in use for a few years and subjected to great loads, that when sections of the various piles become empty, a resurvey of the base will be made.

We have stated that the outside shape can be determined with 3 to 5 per cent accuracy, and although we have the problem of base subsidence, there are ways it can be determined and measured. But if value is finally dependent on weight, what good is 3 to 5 per cent accuracy of volume—if the unit weight used should be in error 25 per cent.

It has been found that the final accuracy of such inventories will likely be more adversely affected by lack of knowledge or inability to determine the average weight per cubic foot of the material in storage than in the determination of the volume itself.

The average weight of coal in storage varies considerably, depending upon the type of equipment used in spreading and compacting the coal, and the degree of fineness to which the coal has been pulverized. The coal in certain of these piles (placed or reclaimed with dragline) has weighed as low as 56 lb per cu ft and in the more recent piles as high as 72 lb per cu ft.

However, it has been TVA's recent experience in the stock piles at the new steam plants that as the operators develop skill in building the pile, the density becomes more uniform, and we are finding considerable equality in the densities of the piles at the several plants independent of the sources of the coal. For these new piles a density of about 71 lb per cu ft has been found to be a good average.

It is axiomatic in such things that the best answer will come from the largest sample. Probably the most satisfactory method for determining density occurs if measurements can be started at the time the stock pile is begun, and after a large amount of coal has been placed, but before any is used, make an aerial survey of its volume. The average density of the pile can then be established by dividing the actual shipping weights by the measured volume.

In the hard packed piles, it is not too difficult to obtain fairly accurate samples near the top of the pile by driving a two cubic foot cylinder, and such equipment as the undisturbed soil samples can take reasonable although small samples from deep in the piles. However, difficulty is still experienced in obtaining adequate samples from the more loosely placed piles.

In covering these last two items, it has not been our intent to discount the photogrammetric survey of stock piles from aerial photography in the least, but merely to indicate that the survey of the exposed portion of the pile is only one of the three major problems in accomplishing such an inventory.

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the relative value of Various Gases for Scarfing

. . . . in analyzing the cost of the various gases for scarfing, many other factors must be considered in addition to the fuel costs . . . . some of these are oxygen cost, flame propagation rates, operational man-hours required to scarf a given amount with different gases and maintenance . . . . in this plant acetylene appears to be the best selection . . . .

▲ AT the Brackenridge plant of Allegheny Ludlum Steel Corp., hand scarfing is the major method of steel surface conditioning on silicon steels. It is also used to edge condition the chromium-nickel 300 series alloy steels. The top and bottom of the 300 series and the straight chrome 400 series alloy steels are conditioned by the mechanical hydraulic swing grinder. The swing grinder is used to obtain a better quality surface.

In the steel industry in general, aside from the special alloy steel groups, scarfing has become the major method of steel defect removal. Scarfing is done at hot rolling temperatures by an in-line scarfing machine ahead or after the rolling mill or by use of the hand scarfing torch on hot or cold metal.

Machine scarfing removes between $\frac{1}{32}$ and $\frac{1}{8}$ in. of the entire metal surface. The criterion which determines the depth of metal removal is the economics of the savings in reduced rejection loss over loss in yield and processing costs.

Modern scarfing machines utilize multiple oxy-fuel gas, slot type tips. A high velocity oxygen jet flows from the center of each of the tips. These tips are arranged to scarf the top, bottom, and edges simultaneously, as the steel is conveyed by the roll tables through the machine. The oxy-fuel gas flame provides the higher flame temperatures, while the high velocity oxygen jet provides the oxidation required to preheat the steel surface to its melting point and oxidize the metal to ferric oxide, Fe_2O_3.

The hand scarfing torch is used primarily as a spot conditioner of the steel surface. The torch has a round or oval shaped oxy-fuel gas tip with a center high velocity oxygen jet. As this is a "start and stop" operation, a $\frac{3}{16}$-in. low carbon starting rod is fed into the preheat flame by the oxygen jet trigger mechanism to facilitate the start of the cut. The rod provides a molten flux on the steel surface which enables the use of various lower flame temperature fuel gases without penalty as to the time required for the start. After the cut is started, the oxidation of the metal defects by the oxygen jet provides the main source of heat for the reaction to continue to take place. During the cut the most minute steel defects show up as irregularities in the cutting oxygen stream and look similar to small streaks of lightning. The heat generated during the cut, when the oxygen and steel burn, opens up, oxidizes, and eliminates the defects. A light flaky ferric oxide remains on the finished surface which must be scraped off to obtain a clean surface.

The fuel gas generally associated with the scarfing process is acetylene. However, other fuel gases such as natural gas, hydrogen, propane, and propane mixtures are available and are often considered as possible scarfing fuels. Natural gas appears especially attractive, because of its low cost per MBtu's. Natural gas is 23 times cheaper per MBtu than acetylene. The question often asked is, "Why cannot cheaper fuel gases than acetylene be used for the scarfing process?" For an answer to this question, one tries to investigate the various characteristics and properties of the available fuel gases from reports found in literature. However, the data contained therein is somewhat vague and often contradictory. Therefore, in order to substantiate and clarify the various claims made for the available fuel gases, one must run a field test on those gases which a preliminary check shows adaptable to the existing economic factors and mill variables of the process requirements.

A preliminary check of the various fuel gas properties usually is limited to an investigation of such items as: (1) the maximum flame temperature of the fuel gas in oxygen, (2) the heat content of the fuel gas, (3) the quantity of oxygen required to burn one cu ft of the fuel gas, and (4) the cost of the fuel gas and required oxygen per MBtu's. However, a more important property appears to be the maximum rate of flame propaga-

TABLE I

The Relative Properties of Various Scarfing Fuel Gases

	Acetylene	Propane M	Propane	Natural gas	Hydrogen
Flame temperature in oxygen, F	5648	4925	4946	5000	5385
Btu content per cu ft	1448	2450	2385	1050	275
Cu ft oxygen per cu ft fuel gas	2.0	3.5	5.0	2.2	0.5
Fuel gas cost per 100 cu ft	$1.70	$3.60	$0.92	$0.05	$1.10
Maximum flame propagation rates, fps	$44.3	$11.9	$12.1	$12.7	$29.2

tion of the fuel gas at the oxy-fuel gas mixture ratio required for attainment of maximum flame temperature.

Table I can be used to demonstrate this point. An analysis of the flame temperatures and Btu content per cu ft of the fuel gases listed shows that the calorific value of a fuel gas is not directly related to flame temperature. Hydrogen with the lowest calorific value at 275 Btu's per cu ft of fuel gas has the second highest flame temperature of 5385 F, while propane M with the highest calorific value of 2450 Btu's per cu ft has a much lower flame temperature of 4925 F. Acetylene, however, with an intermediate calorific value of 1448 Btu's per cu ft has the highest flame temperature of 5648 F.

Further, the rates of flame propagation of the fuel gases follow approximately the rule that the higher the flame propagation rate, the higher the flame temperature. Acetylene with the highest rate of flame propagation has the highest flame temperature, while hydrogen with the second highest flame propagation rate has the second highest flame temperature. Natural gas and propane have lower flame propagation rates and correspondingly lower flame temperatures.

Higher rates of flame propagation cause the fuel gas on intimate mixture with oxygen to be burned and its heat content liberated nearer the torch tip. This allows for a high release of heat content to the most confined or concentrated volume of flue products; i.e., with the least amount of dilution from atmospheric air. Consequently, the greater the rate of flame propagation, the greater the heat transfer rates between the flue gases and the steel surface.

Brucker, Becker and Manthey in 1936 developed as a criterion for fuel gas selection the "specific flame intensity" in Btu's per sq in.-second, which depends on the heat content per cu ft of the fuel gas and the flame propagation rates. These researchers used the bunsen burner cone test to determine the various fuel gases' flame propagation rates and "specific flame intensities." Acetylene had the highest flame propagation rates in mixture with oxygen, followed by hydrogen, manufactured gas, blue gas, methane, propane and finally CO. The highest flame intensity in Btu's per sq in.-sec and the percentage of fuel gas in the oxy-fuel gas mixture giving the highest flame intensity were acetylene 274 (30 per cent), hydrogen 85.5 (75 per cent), manufactured gas 77.5 (58 per cent), propane 65.5 (18 per cent), blue gas 52.7 (80 per cent), methane 51.4 (38 per cent), and carbon monoxide 12.8 (79 per cent). Hence, although the calorific value of a fuel gas is important, the rate of flame propagation is equally important, and together show the degree of "pedigree" of the fuel gases.

Some possible available fuel gases for scarfing are listed in Table I. The respective properties of the fuel gases listed will be analyzed in regards to their value for scarfing. The fuel gases which indicate economic promise will then be chosen for additional field tests.

Acetylene is listed here as it is the traditional fuel gas for scarfing use and has the highest known flame temperature of 5648 F. The high flame propagation rate of acetylene permits a hand scarfing torch tip design which has oxy-fuel mixture outlet holes that terminate at the end of the nozzle. This feature allows maximum entrainment of atmospheric air, which reduces the purchased oxygen requirements of acetylene from a 2½ to 1 oxy-fuel theoretical ratio to a 1.5 to 1 actual ratio. Acetylene also has the lowest oxygen consumption requirements per 1000 Btu's of fuel gas. Hence, acetylene was chosen as a fuel gas for field test comparison.

Propane M is a propane mixture which contains about 82 per cent propane together with various other hydrocarbons of the methane series, to which is added other trade secret volatile ingredients. The trade secret ingredients decrease the oxygen requirements of the fuel gas below that required for propane. Although the initial cost of this fuel gas at $3.60 per 100 cu ft is high, it has a high calorific value of 2450 Btu per cu ft. The high heat content, together with the reduced required oxygen consumption. make this fuel gas appear economically favorable for scarfing use.

TABLE II

Relative Required Preheat Oxygen and Fuel Gas Costs per M Btu

	Acetylene	Propane M	Propane	Natural gas	Hydrogen
Fuel gas cost per M Btu	$0.0117	$0.0147*	$0.0039*	$0.0005	$0.0400*
Oxygen cost per M Btu	$0.0038	$0.0039	$0.0053	$0.0058	$0.0050
Total oxygen and fuel cost per M Btu	$0.0155	$0.0186	$0.0092	$0.0063	$0.0450

*Based on bottled gas prices.

Hence, this fuel gas was chosen as a competitive gas against acetylene for a field test.

Propane is a 99 per cent propane mixture. This fuel gas has the high calorific value of propane M, but at a greatly reduced initial gas cost of $0.92 per 100 cu ft. Therefore, propane was considered a competitor of propane M and was chosen for a field test.

Natural gas is a common fuel gas available at one-eighth the cost of propane. Its lower Btu content is compensated by the compression of the gas to slightly higher pressures than required with acetylene and propane. Due to the similarity of the properties of natural gas with propane, natural gas was not chosen for a field test. The results obtained by tests on propane were to be extended on an equal Btu basis to natural gas.

Another available fuel gas is hydrogen, which has the second highest flame temperature of known fuel gases. Hydrogen, due to its light weight, has the highest Btu content per lb and the lowest Btu content per cu ft. This low heating value of hydrogen per cu ft requires that hydrogen be compressed to higher pressures than acetylene to provide the same quantity of heat per unit area as acetylene. Hydrogen has higher flame propagation rates which prevent the flame from jumping off the torch tip with increased nozzle exit velocities. However, hydrogen has a wide range of oxy-hydrogen mixture ratios, where its rate of flame propagation is high. Hence, hydrogen does not have a special characteristic flame to indicate when a perfect oxy-fuel ratio has been reached. Consequently, flow meter control must be used to determine perfect combustion ratios with hydrogen. Although hydrogen characteristics make it an ideal gas for underwater cutting work, the fuel does not appear favorable for steel mill scarfing and was not tested.

The relative required preheat oxygen and fuel gas costs per MBtu's of the respective fuel gases are listed in Table II. Hydrogen has the greatest preheat flame cost at $0.0450 per MBtu's, which is three times the price of acetylene at $0.0155 per MBtu's. Propane M is slightly higher than acetylene, while propane is about 40 per cent lower in cost than acetylene. Natural gas, however, in regards to the preheat flame cost is the cheapest, being 60 per cent lower in cost than acetylene. In regards to preheat oxygen costs, each of the fuel gases had similar oxygen cost. Hence, the variation in the above overall preheat fuel and oxygen costs results from the fuel gas costs. Ultimately, acetylene, propane M, and propane were chosen for a field test. The purpose of the test was to find the most economical fuel gas in regard to fuel gas and oxygen consumption, scarfing and scraping time, wages and production potential.

For the test an oxygen flow meter with pneumatic transmitter and an orifice in the main oxygen supply line were installed to record oxygen flow. A 0-1000 lb scale (½-lb graduations) and a 0-25,000 lb (10 lb graduations) direct reading scale were installed, balanced, and weight checked.

To eliminate possible differences in scarfing torches, oxygen and fuel gas regulators, gages, and supply line hoses, the same torch outfit was used throughout the test. Each fuel gas supplier recommended the torch tip for the test, which best suited their fuel gas. A No. 62 Linde acetylene tip was used for acetylene and a No. 62 Linde fuel gas tip for the propanes.

Two different test series were run. The first test series were run on the easier to scarf open hearth silicon steels. The second test series were run on the harder to scarf electric furnace grades of silicon steels. Test data accuracy was secured by employment of two mechanical engineers for fuel bottle and slab weighing and two industrial engineers to record actual scarfing and scraping time. The general test procedure was as follows.

Silicon steel slabs of approximately 80 sq ft scarfing area were weighed, scarfed on the top side and one edge completely, scraped on that side and edge, turned over, scarfed on the other side and edge, and reweighed. One scarfer scarfed the top side of the slab; another scarfed the other side. The two scarfers from the first test series who had the best uniform scarfing pace, and who had each equal adequate experience on propane and acetylene scarfing, were chosen by the author and department manager as the scarfers for the second test series.

The slab surface was scarfed by cutting successive continuous channels along the length of the slab. After every two passes the slab was rough scraped to remove excess oxidized scarfed steel. The slab surface was finish scraped at the completion of the scarfing of each side. The scarfing torch was lighted at the beginning of each test and was not extinguished until the top and edge of the slab being scarfed were finished. The scarfers were cautioned to remove all defects and to skin the surface at their normal scarfing pace. The time required to scarf the slab from light-up to shut-off of the torch, the time consumed in the actual use of the torch for scarfing and the time required to clean the oxidized steel slag off the slab by scraping were recorded.

The fuel gas bottles were set on a small platform scale and weighed without their caps. The bottles were manifolded on the scale. Care was taken to prevent bottle location shifting on the scale to obtain accurate weighing. The manifold was removed after each scarfing test and the tanks reweighed.

The oxygen meter was read before and after each test. The meter integrated torch preheat oxygen when the cutting oxygen was in use, but did not record it when the cutting oxygen was not in use. Although the oxygen meter integrator is one of the most accurate obtainable, the cutting oxygen lever on the torch must be held down for 8 sec to allow the mercury column in the meter body to rise from preheat oxygen flow level (no flow condition) to the cutting oxygen flow level. A fuel gas that requires several attempts to maintain a molten pool of metal on the slab surface due to a lower preheat flame temperature would record less than the actual oxygen consumption each time the mercury column differential fell to zero. This would happen continuously if a series of short passes were used in the test. Hence, although the normal hand scarfing pattern on a defective slab is a series of short passes, due to the above condition, successive continuous channels scarfed along the length of the slab was the scarfing pattern chosen for the test.

TABLE III

Results of Test I on Open Hearth Silicon Steels

	Acetylene	Propane M	Propane	Natural gas
Time required to complete scarfing, sec per sq ft	14.7*	15.0	16.0	....
Slab weight removed, lb per sq ft	4.3	4.7	5.1	....
Fuel consumption, Btu per lb metal removed	143	136	134	....
Oxygen consumption, cu ft per lb metal removed	4.05	3.93	3.96	....
Fuel cost, dollar per lb metal removed	$0.0016	$0.0020	$0.0005	$0.0001
Oxygen cost, dollar per lb metal removed	$0.0111	$0.0108	$0.0109	$0.0109
Total fuel and oxygen cost, dollar per lb metal removed	$0.0127	$0.0128	$0.0114	$0.0110

*This figure is biased as one slab scarfed had heavy scabs.

TABLE IV

Results of Test I on Open Hearth Silicon Steels

	Acetylene	Propane M	Propane	Natural gas
Average slab temperature, F	359	359	340	..
Fuel consumption, Btu per sq ft scarfed	616	640	660	....
Oxygen consumption, cu ft per sq ft scarfed	17.3	18.5	20.0	....
Fuel gas cost, dollars per sq ft scarfed	$0.0072	$0.0094	$0.0026	$0.0003
Oxygen cost, dollars per sq ft scarfed	$0.0478	$0.0508	$0.0549	$0.0549
Total fuel and oxygen cost, dollars per sq ft scarfed	$0.0550	$0.0602	$0.0575	$0.0552

The results of test I on the open hearth grades of silicon steel are listed in Table III. The results, based on the weight of metal removed by scarfing, proves that the difference in oxygen and fuel costs between acetylene and propane is the difference in the cost of acetylene over the cost of the propane on an equal Btu basis. As the torch tip nozzles used in the test were of equal Btu input capacity and both had $\frac{5}{8}$-in. cutting oxygen orifices, approximately 137 Btu's per lb of metal removed and approximately 3.98 cu ft of oxygen per lb of metal removed were consumed by each of the fuel gases.

The close similarity of Btu's per lb of metal removed among the fuel gases tested indicates that the heat input required by one fuel gas would equal that of another fuel gas to oxidize the same quantity of steel, where equal oxygen pressure and volume are used. As natural gas properties are almost identical to propane, substitution of the cost of natural gas can be made for the cost of propane on an equal Btu basis to give an indication of oxygen and fuel savings with natural gas. Hence, on the basis of the weight of metal removed, natural gas fuel and oxygen cost were $0.0110 per lb of metal removed, which is $0.0017 per lb of metal removed cheaper than acetylene. Propane M proved to be more expensive than acetylene throughout both test series. Hence, propane M will not be discussed further in this paper.

The relationship between the pounds of metal oxidized and quantity of oxygen required for oxidation is well known. Theoretically, 4.58 cu ft of oxygen are required to oxidize one lb of iron completely to Fe_3O_4. In practice, 2 to 6 cu ft of oxygen are required per lb of iron oxidized, depending on the scarfing process vari-

TABLE V

Results of Test II on Electric Furnace Silicon Steels

	Acetylene	Propane M	Propane	Natural gas
Average slab temperature, F	310	370	410	....
Time required to complete scarfing, sec per sq ft	22.8	27.0	26.8	....
Slab weight removed, lb per sq ft scarfed	6.88	7.80	7.96	....
Fuel consumption, Btu per lb metal removed	137	143	145	....
Fuel consumption, Btu per sq ft scarfed	940	1180	1160	....
Oxygen consumption, cu ft per lb metal removed	4.03	4.01	4.00	....
Oxygen consumption, cu ft per sq ft scarfed	27.8	31.1	31.9	....
Fuel and oxygen cost, dollar per lb metal removed	$0.0126	$0.0131	$0.0115	$0.0111
Wage cost, dollar per lb metal removed	$0.0034	$0.0034	$0.0034	$0.0034
Total fuel, oxygen, and wage cost, dollar per lb	$0.0160	$0.0165	$0.0149	$0.0145
Fuel and oxygen cost, dollar per sq ft scarfed	$0.0874	$0.1021	$0.0920	$0.0880
Wage cost, dollar per sq ft scarfed	$0.0232	$0.0263	$0.0271	$0.0271
Total fuel, oxygen and wage cost per sq ft scarfed	$0.1106	$0.1284	$0.1191	$0.1151

ables. However, the heat input by the torch preheat flame relationship to weight of metal removed is not as easily explained, as 2900 Btu's are evolved by the conversion of one pound of iron to iron oxide. The heat input by the preheat flame is only 137 Btu's by comparison. The answer lies in the angle at which the oxygen jet hits the slab. The hand torch's oxygen jet oxidizes the metal surface by flowing generally perpendicular to the channel scarfed. Hence, only a small part of the 2900 Btu's evolved per lb of iron oxidized is available to raise the adjacent metal surface close to the torch tip to its melting point. The additional energy required must be supplied by the preheat flames. Acetylene with the highest flame temperature has the highest energy or heat transfer rates, and hence is able to scarf at faster rates. The ability to scarf at faster rates is an added flexibility feature of acetylene over natural gas.

Table IV has been prepared to show the results of test I on the basis of sq ft of slab area scarfed, which reflects the scarfing rates of the fuel gases tested. Although only one of the slabs in the test scarfed by acetylene had heavy scabs which consumed extra time to remove, the time required to complete scarfing was lowest for acetylene at 14.7 sec per sq ft scarfed. This was 5.5 per cent faster than the propanes at an average 15.5 sec per sq ft scarfed. Acetylene removed $\frac{7}{64}$ in. of the metal surface, while the propanes removed $\frac{1}{8}$ in. This feature of acetylene is advantageous for hand scarfing, as acetylene scarfed out the defects equally as well as the other fuel gases, yet at a faster rate which reduces the oxygen consumption and weight of metal removed. As the metal difference is yield, the savings can be substantial.

The cheapest fuel gas based on fuel and oxygen cost per sq ft scarfed was acetylene at $0.0550, which was 4.5 per cent cheaper than propane at $0.0575. If the price of natural gas is substituted in the test results for propane, the fuel and oxygen cost for natural gas would be $0.0552 or only 0.3 per cent greater than acetylene. Based on the number of sq ft scarfed, it is the faster scarfing rate of acetylene, which reduces the total oxygen consumption of the main oxygen jet and breaks the balance in favor of acetylene.

The second test series on the electric furnace grades of silicon steel were run to determine the importance of utilizing a "pedigree" gas such as acetylene in the scarfing process. The electric furnace silicon steels are "harder to scarf" due to residuals in surface composition. The tabulated results, listed in Table V, show that because of this "harder to scarf" property, acetylene required 8 sec additional time per sq ft scarfed over the first test series or a 55 per cent increase in required scarfing time. The propanes required an additional 11.5 sec per sq ft scarfed or an 80 per cent increase in scarfing time. Acetylene scarfing rates were 17 per cent faster than the propanes.

Due to the length of time required to complete scarfing, the weight of metal removed per sq ft increased 60 per cent over that removed in the first test series. The propanes removed $\frac{13}{64}$ in. of surface metal or 18 per cent more steel than acetylene which removed $\frac{11}{64}$ in. of surface metal. The depth of metal removed by acetylene was more than sufficient to eliminate all surface defects, but the "harder to scarf" surface of these steels restricted acetylene to a maximum scarfing rate. In fact, with the propanes the "harder to scarf" surface of these steels requires oscillation of the torch tip across the channel being scarfed to keep the slag flowing away ahead of the torch tip. This is not required with the acetylene flame.

Test II showed that, on the basis of total fuel and oxygen cost together with labor cost per lb of metal removed, natural gas was $0.0015 cheaper than acetylene or 10 per cent. Here, as in test I, the savings in costs as based on weight of metal removed cannot be realized due to the metal removal rate being excessive. Hence, for our hand scarfing application, comparison of total oxygen, fuel and wage costs per sq ft scarfed is the better basis for comparison. The total oxygen, fuel and wage cost per sq ft scarfed was $0.1106 for acetylene or 3.1 per cent cheaper than figures computed for natural gas.

The over-all cost of fuel, oxygen, and wages for hand scarfing when based on weight of metal removed are lowest for natural gas, the difference in total costs between acetylene and natural gas being the difference in fuel gas cost on an equal Btu basis. However, acetylene scarfed 5.5 per cent faster than natural gas on the open hearth silicon steels and 17 per cent faster on electric furnace silicon steels. The faster speeds of acetylene allows greater flexibility of the process and increased production potential. In addition, acetylene is required to scarf the electric furnace silicon steels due to its heat resistant surface and to prevent unnecessary yield loss. For these reasons acetylene fuel gas is used for our hand scarfing operations.

If in the future, a hot scarfing machine is installed after our blooming mill, it will for approximately the same reasons be equipped with acetylene fuel. As a large percentage of our silicon steels are rolled direct from ingot to coil, the most versatile fuel gas with the fastest cutting speed decreases the time between drawing the ingot out of the soaking pit to the strip exit from the strip mill. Time saved insures higher strip temperatures on entry to the strip mill, which results in greater accuracy in strip gage and width with least mill power consumption.

As to whether or not acetylene should be used over natural gas for hot scarfing on a carbon mill, the following question should be resolved, "Does the over-all economics of the particular scarfing process dictate the use of acetylene?" If a few cents additional cost per ton for acetylene over natural gas is not offset by some other factor, be it wages, maintenance, production, quality, depth of cut, operator fatigue, burner design, etc., then the use of natural gas can be justified.

SUMMARY

In regard to fuel gas cost, it is worthy of note that although the basic cost of natural gas is 2300 per cent cheaper than acetylene, after the cost of oxygen is added, natural gas costs were only 10 to 15 per cent cheaper. (On the basis of O_2 cost at $0.10 per 100 cu ft, natural gas costs would be 23 per cent cheaper.)

When one investigates this subject further, one finds that with the advent of the 10-in. long continuous slot

type nozzle, another important thing has happened. This slot type tip employs an oxy-preheat fuel mixer quite unlike any to which we are generally familiar with in the steel industry. The tip does not use the familiar premix or nozzle mix, but is a post mix tip; i.e., the fuel and oxygen mix at the end or after the end of the burner tip. The slot type tip, hence, has a center slot for oxygen flow with the fuel gas being added through orifices along the length and on each side of the oxygen flow. A sandwich composed of a layer of fuel gas, a layer of oxygen and a layer of fuel gas results. This allows a stratification of the fuel gas and oxygen, which will allow some of the fuel gas to mix with air and be burned away from the main flame or if the gas velocities are high enough, especially in the case of natural gas, the fuel gas may not be burned but float away from the main flame source and become too lean to ignite. Acetylene with its high rate of flame propagation will no doubt burn more efficiently and effectively than will the natural gas. One company claims that they have not been able to approximate a 1 to 1 Btu input ratio with this method of mixing. They relate that a 1 to 1.45 Btu input ratio is required with the natural gas, which could well be the case. This added fuel gas input will increase the natural gas costs and decrease somewhat the per cent savings of natural gas over acetylene.

One other item worthy of note is the increased maintenance work required with the natural gas machine scarfers. The natural gas scarfing tip must for flame stability be maintained at a distance no greater than $^{13}/_{16}$ in. away from the slab surface, while the acetylene tip is $1\frac{1}{4}$ in. away from the slab surface. This increases the vulnerability of the tip to damage from heavy scabs and slivers. Therefore, the scarfing machines' downtime is greatest with natural gas. As a major producer of quality steels, we know that each unconditioned slab increases our costs considerably. Ultimately, when considering the fuel gas costs for either the natural gas or the acetylene scarfer, we must consider the entire cost picture, not just the superficial costs.

DISCUSSION

PRESENTED BY

R. L. DEILY, Engineer, Air Reduction Co., 150 E. 42nd Street, New York, N. Y.

A. B. GLOSSBRENNER, Assistant General Foreman, Bloom Conditioning, The Timken Roller Bearing Co., Canton, Ohio.

C. J. BURCH, Eastern Manager, Engineering Service, Linde Air Products Co., New York, N. Y.

W. M. BLOOM, Combustion Engineer, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

R. L. Deily: The subject of fuel gases for scarfing is sometimes controversial, so that it is good to have specific information being given. As the author states, there have been published only a few analyses of the engineering factors involved in scarfing, including the fuel gases. Mr. Bloom's analysis of which fuel gas to use also comprises overall scarfing costs and indicates that such cost studies of scarfing practice are very much worthwhile.

Mr. Bloom's conclusion that acetylene is a less expensive fuel gas to use may come as a surprise to some who have looked only at the per cu ft cost of the gases. In my opinion, this points up strongly that the only sound position that any steel mill can take regarding fuel gases is that a complete cost study should be made. Only then can a true conclusion be drawn as to which fuel gas is best to use.

The author mentions a good many of the variables affecting overall scarfing cost. He lists one which was actually the critical factor in this whole study and that is what can be called the cutability of the silicon steels. This cutability is the speed at which these silicon steels can be scarfed as compared, for example, to 0.20 per cent carbon steels. It is interesting that this is the basic factor on which his conclusions are drawn, because the cutability of steels—except for grades like stainless or tool steels—has very seldom been taken into account by anyone reporting on a scarfing study.

So, if any of the steel operating people here are planning similar tests to those reported by Mr. Bloom, it might be well to keep that point in mind: the relative speed of scarfing, the cutability of the steel under different conditions, should be added into the study.

A. B. Glossbrenner: Our practice at Timken is to skin scarf over 95 per cent of our steel in the bloom form. This, of course, includes practically all alloy grades along with many electric furnace silicon steels. Steels above 0.40 per cent carbon are preheated before scarfing. In all cases, our fuel gas is natural gas and has been for five years.

Up to five years ago, we used an acetylene generator to provide our fuel gas. At that time, a revaluation was made.

It was known that on a Btu basis of $1\frac{1}{2}$ cu ft of natural gas to 1 cu ft of acetylene, our generated acetylene cost ratio was 16 to 1 in favor of natural gas. We checked a field test on our scrap burning beds and found that while the preheat time favored acetylene slightly, the overall cutting time came out equal. It was also observed that many of the outside contractors and all of the big scrap yards were going to propane and natural gas if available at high pressure.

These findings were then added to other advantages in favor of natural gas:

1. Natural gas at 50 psi delivered pressure offered a much more reliable source of fuel gas than the acetylene generator.
2. After having an acetylene generator in our plant blow up and one in a neighbor's yard repeat the performance shortly afterwards, acetylene generation was considered a dangerous operation.
3. Torch maintenance is less with natural gas. With acetylene exploding by itself at 15 psi pressure, we had many torches damaged by mixer tube explosions.

I should note here that we have had no torches damaged by such explosions since going to natural gas. Also there has been no increase in our tip maintenance cost.

As to speed of scarfing, we use the No. 62 natural

gas tip with about 75 psi blow pipe O_2 pressure and have scarfed 9 x 9½-in. blooms at 10 tons per net man-hour. This average includes electric furnace silicon steels.

It is our observation at Timken that the amount of metal removed depends on the scrap and the speed at which the scarfer is willing to work. It is also interesting to note that scarfing slag does not cling as tightly to a bloom scarfed using natural gas as to one where acetylene was the fuel gas.

C. J. Burch: The author's analysis on the theory is good. In essence he says that the best Btu's are those that get directly into the starting puddle. Acetylene burns in a more concentrated area, driving heat in faster, and the Btu's get into the puddle and that is where they count. He also brings out that there is a difference in cost and, if other factors were equal, results should be in favor of the lowest cost gas.

Then he reports the actual fact. He runs his test as accurately as he can, under his conditions and on his steel, and in essence comes up with the conclusion that the extra speed using the acetylene more than overcomes the extra cost of that acetylene.

Now, you have heard Mr. Glossbrenner and others. But from Mr. Bloom's tests, he has come up with the answer that is best for his work. All operators actually should take into account not only the theory but the practice. When these various tests are analyzed, you will find that by-and-large there is very little margin between a cheap good gas (natural gas is good) and acetylene, which is more expensive but of a better quality for preheating.

The net over-all result, in Mr. Bloom's application, is that acetylene came out ahead. But, again, here we are talking about an extremely small difference and so, in the over-all picture, may the best gas win.

W. M. Bloom: The only comment I would like to make is in regards to Mr. Glossbrenner's comments. One must remember the fact that when you try to scarf an easily scarfed carbon steel, the difference in the respective speeds, the maximum scarfing speeds of the different gases, may not show up or be apparent, because on the carbon steels, the man is the important factor. This is especially true, if one might be working hot steel. I do not think the man would be too energetic with the hand scarfing torch, when scarfing hot steel, so that the maximum scarfing rates would be reached.

But in regard to scarfing speeds with a heat resistant, harder to scarf, silica steel or, as I earlier stated, a steel that has a heat resistant residual in the steel surface—the residuals apparently come from the type of mold coating used—and when you try to scarf this type of steel, then the difference in maximum possible scarfing speeds is apparent.

Machine scarfers also show the possible difference in scarfing speeds when using natural gas and when using acetylene. When scarfing 5 to 8 point carbon bottle top steel at 2050 F, natural gas machine scarfers scarf at the rate of 100 fpm, while acetylene machine scarfers on the same steel and same temperature scarf at 110 fpm.

As regards explosion hazards, we all know that natural gas can be dangerous, as dangerous as acetylene. When it comes to backfiring torches, the lower flame velocity of natural gas is the answer to why the torch does not readily backfire with natural gas. However, with due respect to acetylene's higher flame speeds and with immediate shutoff of the fuel valve with the start of a backfire, backfire in an acetylene torch has yet to cause a mixer tube explosion at our plant. Each and every fuel gas with an appreciable Btu content has a definite explosive hazard. If any of you have ever had a natural gas explosion, you know it may be a less harsh force with less detonation or not quite as violent in manner as acetylene, due to the difference in time required for the reaction to take place, but a natural gas explosion can cause a lot of trouble.

As far as the slag not sticking to the steel surface with natural gas, here, again, I believe this may be true. Natural gas being a lower temperature fuel gas than acetylene would not raise the steel slag to quite as high a temperature and fusing of the slag to the slab surface may not be as great.

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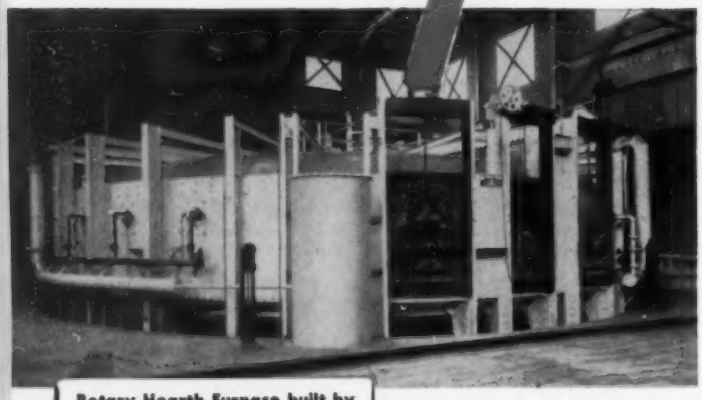

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A Practical Suspension for Insulating Refractory Walls and Arches

▲ Prior to a new development by the Geo. P. Reintjes Co., the suspending of insulating wall and arch tiles had been complicated due to the fact that very few manufacturers were able to make tile shapes. Most refractory companies form and burn "biscuits." The desired brick shape is then sawed or ground from these biscuits.

Notches or grooves that were required in the tiles to accommodate the hanger had to be sawed or drilled. The refractories, being very abrasive, soon cut the hardest of tools. The maximum size of the tiles that most factories can grind from the biscuits is 3 x 4½ x 9 in.

The suspended insulating refractory arch which has been developed by the Reintjes Co. employs a method of using a stainless steel supporting clip, one end of which is impaled between a pair of brick. The other end of this support is so designed as to hang over a rod much the same as clothes are hung on a line.

The opposing faces of the bricks are dipped in air-setting high temperature bonding cement before impaling the clips and then hung in pairs on pre-spaced rods. The clips extend beyond the refractories and are of sufficient length so that insulation of suitable thickness can be applied. The supporting rods in turn are supported from tubing on approximately 18-in. centers.

The suspended insulating refractory walls developed by the Reintjes Co. are similarly supported. The bottom row of the tiles rest on the horizontal leg of an angle which has been previously attached to the vertical column. Rods at suitable intervals, are fastened to these angles. The wall tiles are then laid in a manner similar to the building of gravity walls.

Stainless steel anchoring supports are hooked over the rods. Their inner ends are impaled in the brick. The sectional suspending of the wall is accomplished by spacing the supporting angles 2 to 4 ft apart, and having offset expansion joints occurring at the support angles.

With this design, the vertical supports, with exception of the impaled stainless steel anchors, are located outside of and spaced away from the refractories. Insulation, either plastic or block, can be readily applied to the outside of the wall.

By using 3-in. brick, standard insulation blocks of 6-in. width can be installed without cutting. This applies to both the wall and arch described above. This construction is proving to be the most economical and practical support to date developed.

Figure 1 — By cementing pairs of insulating brick on the suspension clip in advance, erection is simplified and time is saved.

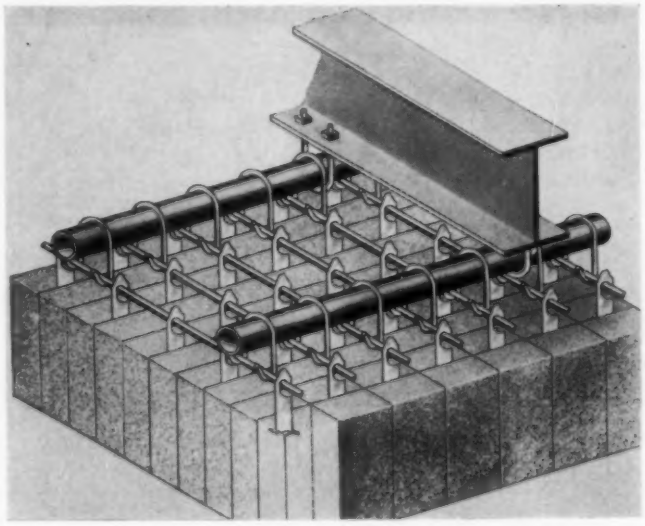
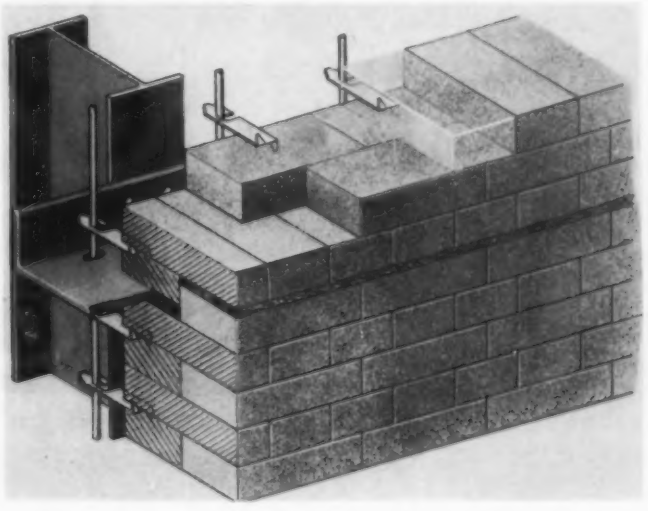


Figure 2 — Standard 3 x 4½ x 9-in. insulating fire brick are used, laid in all header courses, or preferably alternate headers and stretcher courses.



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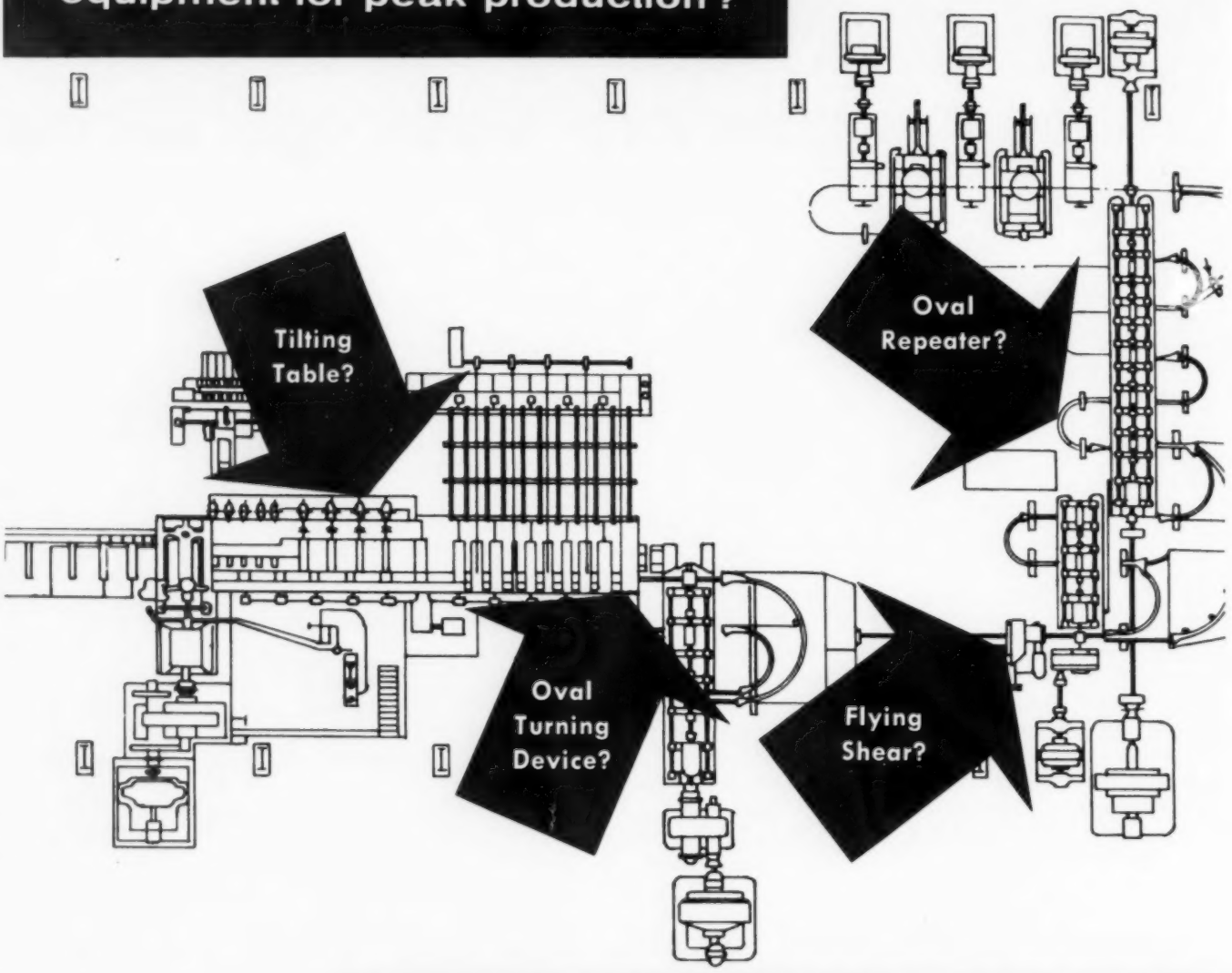

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X-RAY SPECTROGRAPH Eliminates Production Bottleneck

By VERN W. PALEN

North American Philips Co., Inc., Mt. Vernon, N. Y.

▲ DURING 1955, Copperweld Steel Co., Warren, Ohio, faced a difficult problem because of zooming demand for leaded alloy steels, essential to industry for better tool life and lower production costs. All orthodox methods for checking the lead content of the steel were much too slow to keep up with constantly-growing mill output. Today, with the x-ray spectrograph, data is obtained accurately in one-fourth the time and an unskilled operator can do the job easily.

Here are the actual figures on time required to determine lead content for a heat of twenty ingots of Copperweld leaded steel by three different methods:

	Specimen preparation, hr	Overall, hr
Chemical (gravimetric)	1½	30 to 40
Emission spectrograph	3	4 to 5
X-ray spectrograph	negligible	1

Leaded alloy steels contain uniformly dispersed, finely divided particles of lead in quantities ranging from 0.15 to 0.35 per cent. Although the lead has little or no effect on the physical properties of the steel, it does have great value in subsequent machining processes. Copperweld Steel Co. has developed special techniques by which alloy grades of steel are permeated with a material such as lead having a high gravity and low melting point.

Since the vaporization point of lead is 2950 F, it is close to the tapping temperature of the steel as it comes from the furnace. Thus, it would be difficult to be certain of its retention or uniform dispersion if it were added to the bath of molten low carbon steel. For this reason, particles of proper size must be added in the mold so they will be carried well below the surface while the lead is still in the solid state.

Actually, solid lead particles are injected into the ladle stream under air pressure. With this procedure, the particles become molten while submerged in the liquid steel. Surface tension and ferrostatic head of the

TABLE I

Comparative Analyses of Leaded 4140 Steel

	C	Mn	P	S	Si	Cr	Mo	Pb
Spec.	0.38/0.43	0.75/1.00	0.04 max	0.04 max	0.20/0.35	0.80/1.10	0.15/0.25	0.15/0.35
Ladle No. 1	0.40	0.83	0.011	0.022	0.26	0.96	0.16	....
Ladle No. 2	0.41	0.82	....	0.022	0.25	0.95	0.16	....
Ladle Check	0.40	0.81/0.81	....	....	....	0.97	....	....
Blooms 1T	0.43	....	....	....	....	....	....	....
1B	0.40	....	....	....	....	....	....	....
19T	0.43	....	....	....	....	....	....	....
19B	0.40	0.81	....	....	....	0.98	....	....
Final analysis	0.41	0.81	0.011	0.022	0.26	0.97	0.16	0.15/0.35

Lead checks (ingot)

Bloom	Lead	Bloom	Lead	Bloom	Lead	Bloom	Lead	Bloom	Lead
1T	0.22	5T	0.20	9T	0.22	13T	0.21	17T	0.21
1B	0.23	5B	0.21	9B	0.22	13B	0.24	17B	0.20
2T	0.21	6T	0.21	10T	0.20	14T	0.21	18T	0.20
2B	0.23	6B	0.22	10B	0.21	14B	0.21	18B	0.21
3T	0.21	7T	0.21	11T	0.21	15T	0.20	19T	0.21
3B	0.22	7B	0.21	11B	0.22	15B	0.22	19B	0.21
4T	0.21	8T	0.21	12T	0.21	16T	0.20		
4B	0.21	8B	0.20	12B	0.23	16B	0.18		

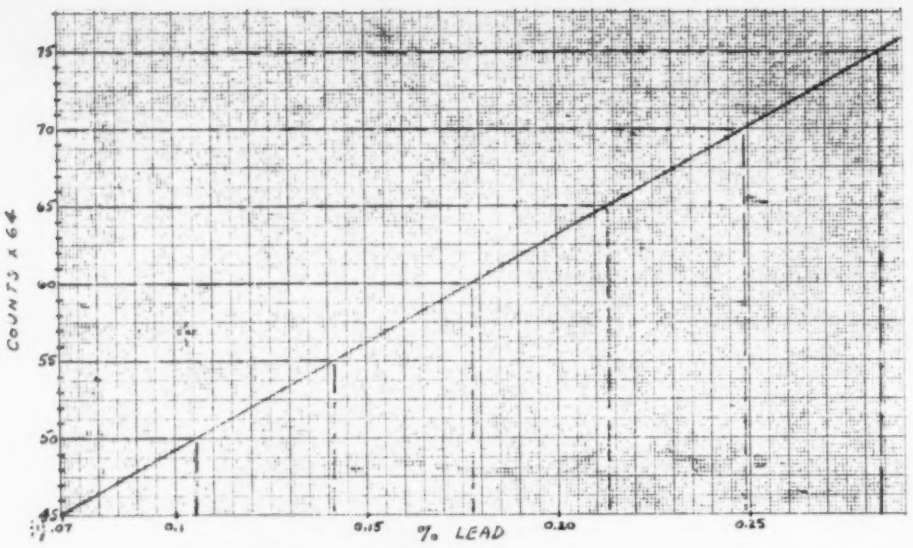


Figure 1 — This graph is used by x-ray spectrograph operator to convert instrument counts into corresponding per cent lead values.

steel cause the lead particles to assume spheroidal shape. This minimizes any tendency of the lead to create stresses or to adversely affect physical properties.

Concentration of lead at the bottom of the ingot is avoided by carefully controlling the time interval between the start of the pour and the start of the lead addition. Now, the Copperweld process is so well established that the company adds lead as a regular routine to virtually all grades of alloy and carbon steels to suit customer specifications.

Table I shows the complete analysis of a heat of type SAE 4140 leaded steel. When the company began production of such metals, lead content was determined chemically from drillings taken from rolled sections of the heat.

As production increased, Copperweld Steel Co. cut the time required for lead determinations by using an emission spectrograph. With this instrument, drilling and briquetting proved to be a lengthy chore and eventnally analysis work fell behind schedule again. At this stage, backlogs of 50 to 75 heats were frequently delayed in processing because lead content had not been determined.

Copperweld and Philips engineers cooperated in the design and development of an x-ray spectrograph especially suited to this particular application. The unit incorporates an x-ray tube mounted beneath a flat metal table so the rays strike the specimen from below. The table accommodates specimens 2 to 10 in. sq.

The operator places a specimen in position on the table, closes the rayproofed cover, then presses a button on the control panel. A timing device automatically turns the power off after a selected interval. Total pulse count is observed on an instrument dial.

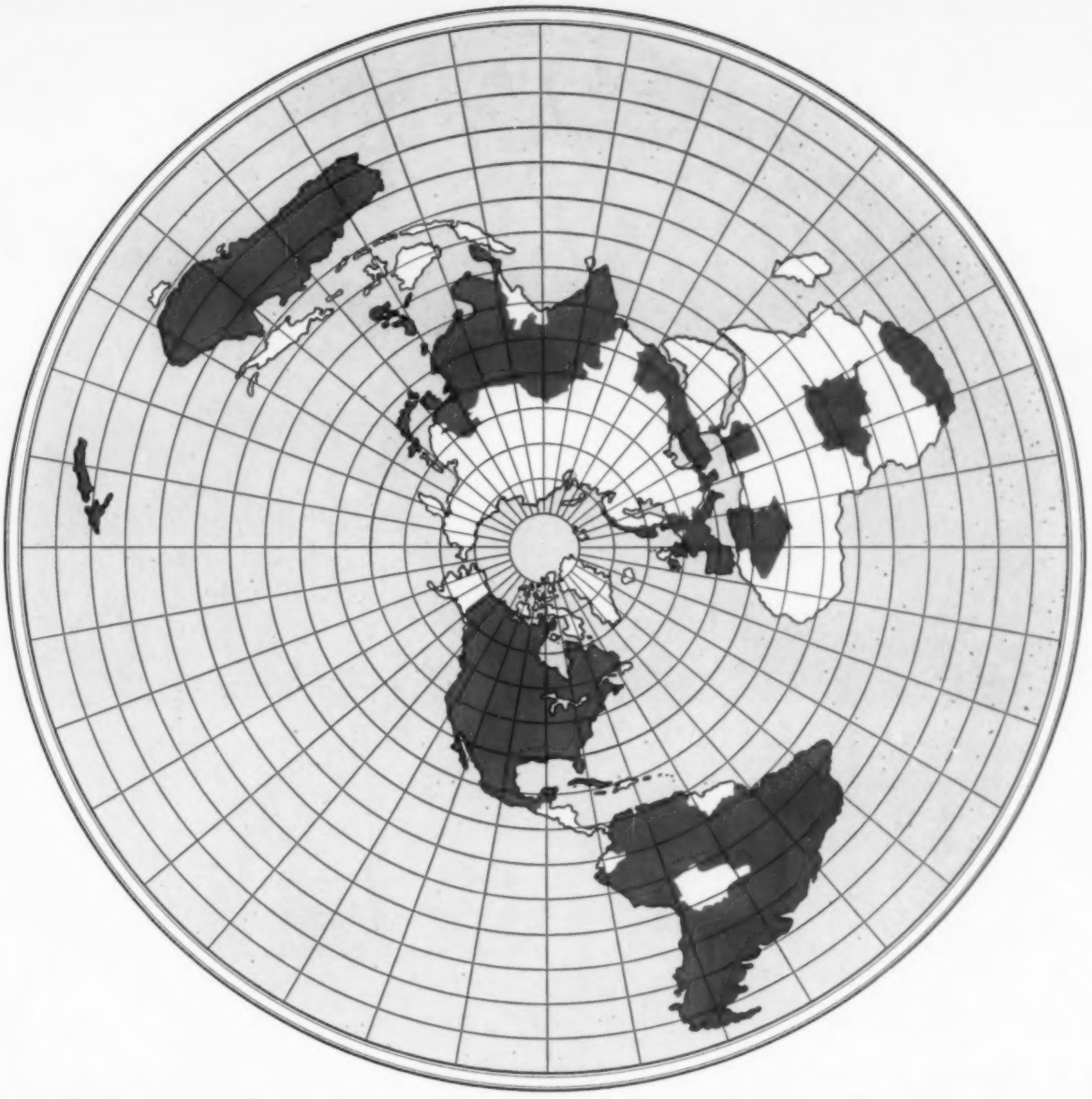
Figure 1 is a graph that converts counts into per cent lead. For Copperweld work, the multiplier switch is permanently set on 64. This means the actual total count equals the meter reading times 64. The multiplier setting is varied higher or lower to accommodate greater or smaller concentrations of elements being measured.

To properly understand all details of Copperweld's present method, let us start with a ladle full of steel, commonly called a heat. When this metal is ready for pouring, a crane moves it into position over a series of 20 ingot molds until all are filled. Molds are 18 in. across because this is the largest size the mill can roll.

Next, ingots are rolled into blooms or billets. Rough ends are cut off with a hot saw and four-in. specimens are taken to represent top and bottom of the ingot. The four-in. specimens are stamped with heat number, ingot number and position and are then sent to the cold saws. Here, they are cut into segments 2-in. thick to provide two duplicate sets of forty coupons from each heat.

After identification by cold stamping, one set of coupons is loaded onto a conveyor cart and is delivered to the operator of the x-ray spectrograph. The other set is used for the sweat test which indicates whether or not lead is uniformly distributed. Since the x-ray analysis is nondestructive, after they undergo this procedure the coupons are used again for the etch test in order to check soundness and segregation.

Figure 2 — Operator is placing a specimen (coupon) of alloy steel in position on the x-ray spectrograph.



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Corhart Electrocast Refractories are currently being used in 50 countries on 6 continents, as indicated by the colored areas above!

Progressive manufacturers the world over know they can rely on Corhart products for the utmost in refractory dependability and operating economy.

QUALITY ECONOMY ENDURANCE

CORHART ELECTROCAST REFRACTORIES

The words "Corhart", "Zac", and "Electrocast" are registered Trade Marks which indicate manufacture by Corhart Refractories Company, *Incorporated*, Corhart Refractories Company, *Incorporated*, 1600 West Lee Street, Louisville 10, Ky., U.S.A.—Telephone CYpress 4471.

MAKE SURE YOUR NEXT BULK MATERIALS HANDLING BRIDGE HAS THESE IMPORTANT DRAVO FEATURES:

- Liberal Use of Welded Components
- Double Web Truss System with Beam Sections
- Positive Wind Protection with Dravo Rail Clamps
- Fully Equalized Loading on Truck Wheels
- Use of Unit Construction for Mechanical Elements

TROLLEY ACCIDENT PREVENTION WITH DRAVO HYDRAULIC BUFFERS

This six-foot stroke hydraulic buffer, installed on end of ore bridge span, provides safe stop for a 120-ton man trolley traveling at 900 feet per minute.

DRAVO Ore Bridges . . .

Hydraulic Buffers Stop Trolley Safely at any Speed

The use of hydraulic buffers is one example of how Dravo builds efficiency and safety into ore bridges. Operators work more efficiently when safety is assured by smooth, hydraulic-buffered stops. In fact, every Dravo bridge is individually designed to handle its specific job not only safely, but also dependably and economically. Such performance is made possible by bringing together the customer's operating knowledge and the experience of Dravo's research, design and construction men.

This method has resulted in high efficiency bridges and other bulk materials handling equipment that produce because they are tailored to fit the job. Dravo engineering features, built into every structure, provide for low maintenance and operating costs. For complete information on Dravo ore bridges and unloaders, write to Dravo Corporation, Pittsburgh 25, Pa.

DRAVO
CORPORATION

Blast furnace blowers • boiler and power plants • bridge sub-structures • cab conditioners • docks and unloaders • dredging • fabricated piping foundations • gantry and floating cranes • gas and oil pumping stations • locks and dams • ore and coal bridges • process equipment • pumphouses and intakes • river sand and gravel • sintering plants • slopes, shafts, tunnels • space heaters • steel grating • towboats, barges, river transportation

Copperweld Steel Co. runs approximately 500 x-ray tests for lead in an 8-hr day. The x-ray operator uses a standard specimen to check accuracy at the start and finish of each record sheet. In operation, a coupon is placed on the table, the cover is closed and the button starts the count which continues for 23 seconds. When the timer cuts off the x-rays, the lid is raised, the coupon is turned 90 degrees about a vertical axis, and the count is repeated. The double test on the coupon takes less than one minute.

The new x-ray method is very simple when compared to chemical tests which require 1-in. holes to be drilled in each coupon at a point halfway between the center and edge. The x-ray spectrograph analyzes a 1¼-in. area at the same location without drilling out material and without destroying the specimen. When Copperweld used the emission spectrograph, similar drillings were required and this material had to be seived to obtain particles of a size that would pass through a 12-mesh screen but stay on a 40-mesh screen. Then, these particles had to be briquetted before they were ready for test. Savings in time and money are readily achieved with x-rays because this one-step procedure is an adequate substitute for other more complicated methods.

Lead determinations and operation of the x-ray spectrograph are the direct responsibility of Roy Lab, chief chemist at Copperweld's plant at Warren, Ohio. He also played an important role in designing the special bulk specimen installation. Ross Burrier, x-ray spectroscopist, directs instrument operation.

At the present time, production of leaded metals is expanding rapidly and includes all SAE grades of carbon steel as well as chrome-nickel, chrome-molybdenum, and nickel-molybdenum steels. Because the lead does not combine with the steel as an alloy but is held in mechanical suspension throughout the ingot, it serves as a lubricant. Because of this, tool life in machining operations frequently is improved 200 per cent and production rates from 50 to 300 per cent.

Copperweld Steel Co. began making copper-coated alloy steel wire in 1915 with a crew of 23 men. Today, this organization has plants at Glassport, Pa., Oswego, N. Y., and at Warren and Shelby, Ohio. With 4500 employees, the company now has an annual ingot capacity of 618,000 tons. Copperweld steels are produced in electric arc furnaces and these units make up 6 per cent of the U. S. installations of this type.

The Warren plant with 2700 employees produces alloy steels of all specifications and rolls them into bars, blooms and billets. Facilities include seven electric furnaces, 29-in. mill, 21-in. mill, 18-in. and 12-in. mill, and conditioning, finishing, cold draw and concrete reinforcing bar departments.

With steel production in this country headed toward higher levels in 1956, advanced technology becomes increasingly important. Copperweld Steel Co. continues to keep pace with the most modern scientific trends through the use of x-ray equipment for production control problems.

How to cut mill downtime due to bearing failures...

use A·B·K* bearings

Roll neck and slipper bearings made of A-B-K material often outwear metal bearings many times. Their ability to cushion impact loads without peening, scoring or heat-checking protects roller necks, housings and chucks. Simplicity of design and light weight speed installation. Can be lubricated with grease, oil or water *alone*. Ask our engineers to help you solve your specific problems.

- Wear longer
- Won't score or heat check
- Light in weight
- Cut lubricant costs
- Save power

A·B·K
LAMINATED
PHENOLIC BEARINGS

*A registered trade-mark of American Brake Shoe Company in the United States and of Joseph Robb & Company, Limited, in Canada.

American Brake Shoe Company
AMERICAN BRAKEBLOK DIVISION
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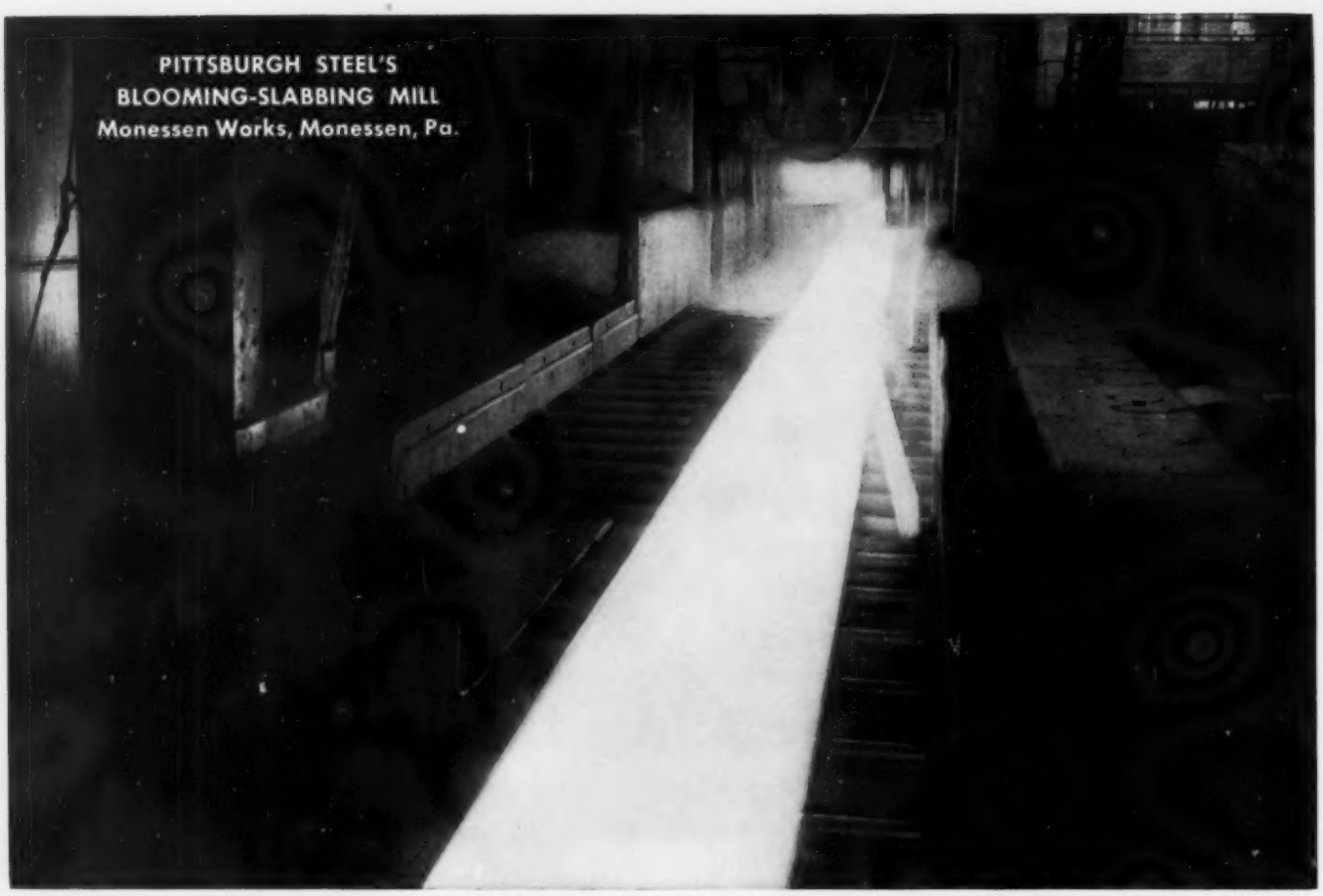
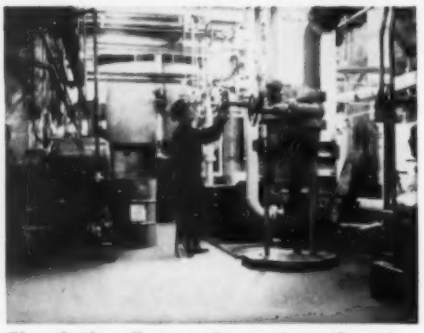
In Canada: Joseph Robb & Co., Ltd., Montreal, Quebec

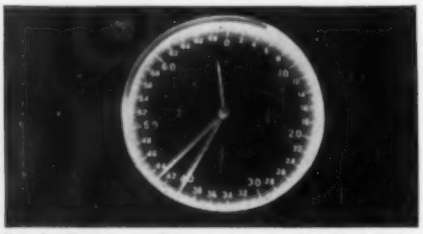


Time exposure shows continuous motion of red-hot ingot as it travels through roller.

"Never replaced screwdown or nut using Cities Service E. P. Lubricants!"



Circulating System located on floor below mill, uses Cities Service E. P. Oils. Mill operates 160 hours a week, has never had lubrication failure.



Dial Gauges Accuracy to 1/32 of an inch. It is used by operators in the pulpit, who control the mill's 7000 horsepower and shape its steel to unusually fine tolerances for a blooming operation.

Ever since the installation of this blooming-slabbing mill at Pittsburgh Steel Company's Monessen Works, Cities Service E. P. Oils have been used for lubrication.

During that time, over 4,000,000 tons of steel have been run through the mill's huge rolls . . . but never once has the firm found it necessary to replace the screwdown, nut or any bearing due to lubrication failure.

A Pittsburgh Lubrication Engineer says: "Oils stay with the parts that must be lubricated and never give us a problem."

Where an inferior lubricant might be wiped away during the regular operation of the mill, Cities Service E. P. Oil withstands continuous operation. In addition, the oil can be centrifuged and yet not lose its additive.

Pittsburgh Steel is one of an increasing number of steel manufacturers who report outstanding results with Cities Service Lubricants. A Cities Service Lubrication Engineer will be happy to supply all the reasons. Or, if you prefer, write Cities Service Oil Company, Sixty Wall Tower, New York 5, New York.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

BLAW-KNOX makes what it takes

for continuous, mechanical chipping

The Continental Chipper with auxiliary equipment is a complete mechanical system for sorting, handling, inspecting and chipping billets. This integrated system has demonstrated in-service cost savings over manual conditioning. It represents a wise investment in long range modernization programs for conditioning for subsequent rolling in merchant and bar mill operations.

Product quality improvement is immediate, positive. Precise chipping is accomplished by a non-traveling cutter head under which the billet moves in a fashion similar to a milling machine. All chipping is done at close range, immediately in front of the operator. This single operator, located in front of the cutter head controls the entire operation including all material handling.

The chipper is equipped with special interlocking devices which eliminate unsafe operation. Usual chipping bay hazards such as high pressure air lines, improperly handled chisels, and flying chips are removed. The Continental Chipper accommodates billets up to 30 feet in all merchant and bar mill sizes.

For complete details, write for illustrated booklet.

50th Anniversary
BLAW-KNOX
1906-1956

BLAW-KNOX COMPANY
Foundry and Mill Machinery Division
Blaw-Knox Building • 300 Sixth Avenue
Pittsburgh 22, Pennsylvania

CONTINENTAL

JAMES E. DAVIS CHIEF ELECTRICIAN
NORTHWESTERN GLASS CO.

"Our Production schedule was frequently disrupted by needless shutdowns on a line of motors . . *until we changed to Fusetron Fuses*"

James E. Davis,
CHIEF ELECTRICIAN, NORTHWESTERN GLASS COMPANY
SEATTLE, WASHINGTON

"Ordinary 500 amp. renewable fuses were blowing frequently in a 1000 amp. switch that controls a line of motors ranging in sizes up to 150 hp.

"We work on a tight production schedule, so these shutdowns with men and motors standing idle were costing us a considerable amount of money and trouble.

"As chief electrician, the problem was 'thrown in my lap'.

"A study of the situation indicated that harmless surges were causing the fuses to blow.

"We figured that the long time-lag of Fusetron dual-element fuses might correct the trouble.

"They were installed in 1953 and the original Fusetron fuses are still in service.

"We think this is quite a record because the switch is loaded to capacity 24 hours a day 7 days a week, only Christmas and July 4th excepted."

Here's why Fusetron Fuses give all purpose Protection

A fuse link combined with a thermal cutout - the result, a fuse with tremendous time-lag and much less electrical resistance and an interrupting rating in excess of 100,000 amps.

They have the same degree of Underwriters' Laboratories approval for both motor-running and circuit protection as the most expensive devices made.

Made to same dimensions as ordinary fuses. FUSETRON Fuses fit all standard fuse holders.

Obtainable in all sizes from 1/10 to 600 amperes, both 250 and 600 volt types. Also in plug types for 125 volt circuits.

Their cost is surprisingly low.

Write for bulletin FIS.

THOMAS F. CURRAN
MACHINE OPERATOR

FOR LOADS ABOVE 600 AND UP TO 5,000 AMPS., USE BUSS Hi-CAP FUSES . . .

They have unlimited interrupting capacity to handle any fault current regardless of system growth.

They can be coordinated with Fusetron fuses on feeder and branch circuits to limit fault outages to circuit of origin.

Write for bulletin HCS.

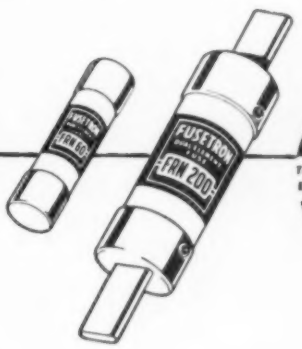
FUSETRON DUAL-ELEMENT FUSES DO MORE THAN ELIMINATE DOWN PERIODS CAUSED BY NEEDLESS BLOWS . . .

They Provide 10 Point Protection . . . .

1. High interrupting capacity — protect against heaviest short-circuits. Have proven on tests to open safely on circuits set to deliver in excess of 100,000 amperes.
2. Protect against needless blows caused by excessive heating — lesser resistance results in cooler operation.
3. Protect against needless blows caused by harmless overloads.
4. Provide thermal protection — for panels and switches against damage from heating due to poor contact.
5. Protect against waste of space and money permit use of proper size switches and panels.
6. Protect motors against burnout from overloads.
7. Give DOUBLE burnout protection to large motors — without extra cost.
8. Protect motors against burnout due to single phasing.
9. Make protection of small motors simple and inexpensive.
10. Protect coils, transformers and solenoids against burnout.

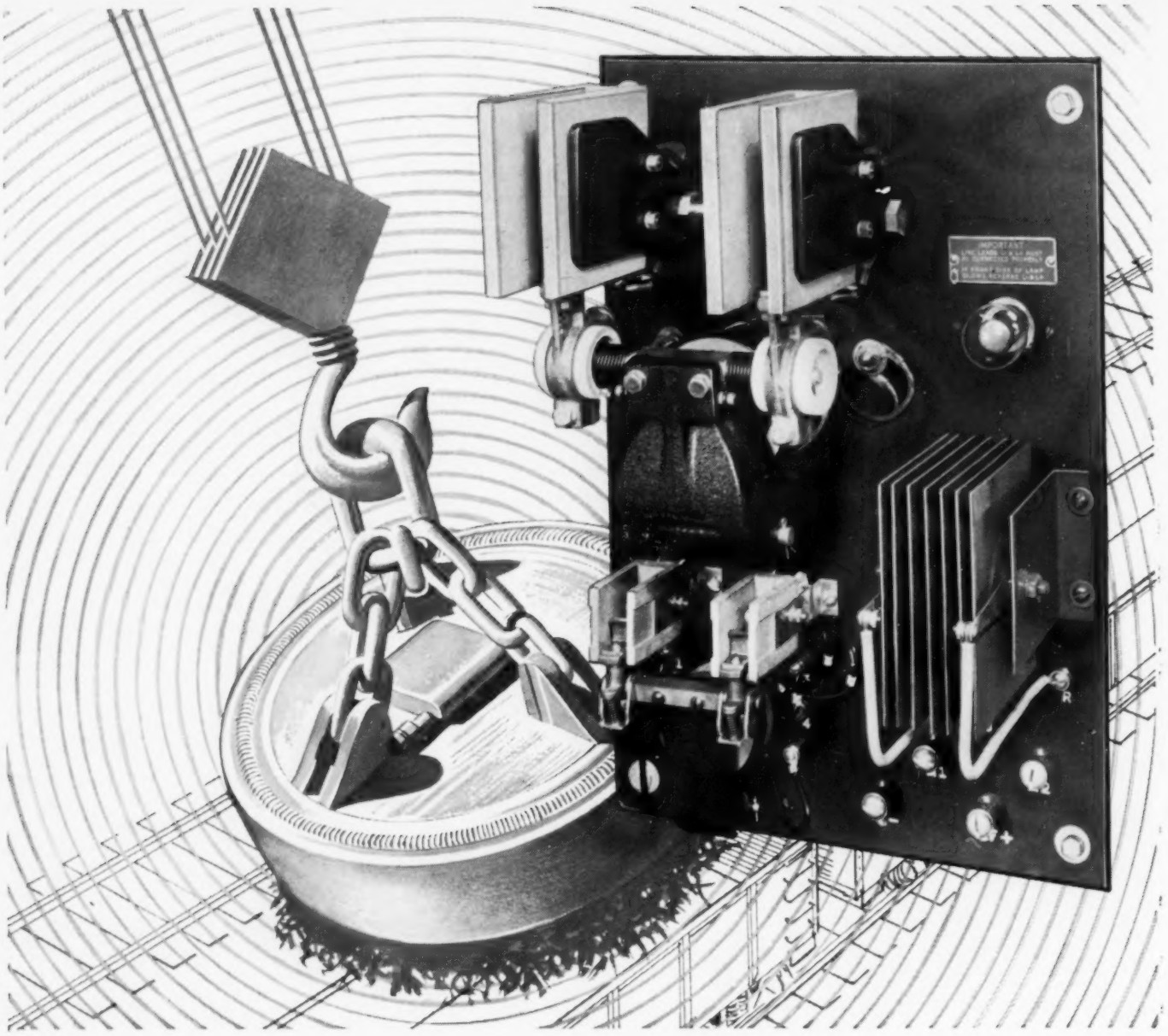
Play Safe! install FUSETRON dual-element Fuses and BUSS Hi-Cap Fuses throughout entire Electrical System!

BUSSMANN MFG. COMPANY
(Division of McGraw Electric Co.)
UNIVERSITY AT JEFFERSON ST. LOUIS 7, MO.



FUSETRON
TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION
BUSS

1156



Ohio Electric Manufacturing Co. guards against arc damage *with J-M Ohmstone panels*

Ohio Electric Manufacturing Co. has long been known for the dependability and durability of their magnets. Exacting care is employed both in construction and selection of materials. Among these is Johns-Manville Ohmstone used as the panel board in the magnet control element. Especially designed and constructed for unusually dusty conditions, Ohmstone incorporates exceptional arc resistance and high dielectric strength.

Made of asbestos, cement and a water-repellent ingredient, Ohmstone is bonded under pressure and impregnated with a non-carbonizing insulating compound. It withstands shock and vibration . . . won't rust or rot . . . resists water, oil, gas, ordinary chemicals and sudden temperature changes.

Ohmstone can be machined and drilled to accommodate apparatus. For further information write to Johns-Manville, Box 14, New York 16, N.Y. In Canada: 565 Lakeshore Road East, Port Credit, Ontario.

Johns-Manville OHMSTONE® AN ASBESTOS PRODUCT

JOHNS-MANVILLE JM PRODUCTS

McKee expands again to give you

BETTER ENGINEERING AND CONSTRUCTION SERVICES

One of 15 specialized engineering groups in the McKee organization.

THERE are good reasons for the continuous growth of the McKee organization. Because of broad expansion of the industries we serve, our specialized, world-wide services are in greater demand than ever before in our fifty-year history. This demand, in turn, creates unusual opportunities which attract additional engineering and technical experts to the large McKee staff.

To accommodate our expanded organization McKee added the modern 25,000-square-foot building shown here. Every feature of layout, lighting, air conditioning, sound insulation and efficient equipment was designed with one purpose in mind—to give you better engineering and construction services.

Ideal working conditions contribute to the efficiency of McKee engineers. Private offices and drafting rooms have modern ceiling lighting, air conditioning, floor and ceiling sound insulation and latest engineering equipment.

Arthur G. McKee & Company • Engineers and Contractors

Headquarters: McKee Building • 2300 Chester Avenue • Cleveland 1, Ohio
Offices: New York, N. Y. • Union, New Jersey • Washington, D. C.
British Representatives of Metals Division: Head, Wrightson & Co., Limited
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McKee
ENGINEERING & CONSTRUCTION
Services

how would you like to add $250,000.00 to your profit?

Dowell Chemical Cleaning Made This Possible for an Industrial Plant!

In 1954 an East Coast plant employed Dowell Chemical Cleaning Service on a limited basis. The results were encouraging.

In 1955 the same company expanded its use of chemical cleaning. The results were startling. More throughput, less down time, and greater overall plant efficiency effected nearly a *$250,000.00 saving!*

In 1956 the program was continued. The result: still more savings. Eventually, chemical cleaning on a continuing year-around basis is expected to effect savings of from $300,000.00 to $500,000.00 annually.

This case history is about an oil refinery. However, Dowell has eye-opening performance data to show you in almost any industry.

Dowell engineers are experts in the use of solvents to remove scales and sludges—those deposits that cut the capacity of process and steam generating systems. Dowell does the job for you and furnishes all necessary chemicals, trained personnel, pumping and control equipment.

For additional information, call the Dowell office near you. Or write Dowell Incorporated, Tulsa 1, Oklahoma.

clean it chemically DOWELL

A SUBSIDIARY OF THE DOW CHEMICAL COMPANY

Date-line Diary...

November 1

▲ Electro Metallurgical Co., announced a reduction of 30¢ per pound of contained tungsten of all tungsten alloys.

▲ Chrysler Corp. reports sales for the first three-quarters of 1956 of $1,858,437,251 compared with sales of $2,466,251,614 for the same period of 1955; net earnings for the same periods were $6,272,352 or 72¢ per share compared with $70,637,012, or $8.11 per share.

▲ First nine months sales for 1956 as reported by Allis-Chalmers Manufacturing Co. totaled $432,000,000, with net earnings of $1.87 per share. For the same period last year, sales were $396,500,000 and net earnings $2.21 per share.

November 5

▲ Personal income annual rate reached an annual rate of $328,500,000,000 in September, $400,000,000 above the August, 1956 pace, and $17,500,000,000 over the September, 1955 level. For the first nine months of 1956, Americans earned 6½ per cent more than in this same period in 1955.

▲ The AISC reported bookings for September 1956 of 245,617 tons compared with 268,273 tons in August 1956 and 339,461 tons in September 1955. Shipments in September, 1956 totaled 240,858 tons compared with 213,495 tons in August, 1956 and 289,128 tons in September 1955. Backlog at the end of September totaled 3,107,874 tons.

▲ The AISI reports estimated payroll for the iron and steel industry for September, 1956 at $338,990,000. Average hourly payroll cost of wage earners was $2.784 for each hour worked during September compared with $2.697 in August. In addition to the above, the hourly cost for pensions, social security, and insurance amounted to 25.0¢ per hour. Working hours averaged 39.2 hr per week in September compared with 34.2 hr per week in August. Estimated number on payroll was 687,900.

▲ The AISI reports that the operating rate of the steel industry for the week of November 5 is scheduled at 100.6 per cent of capacity. This is equivalent to 2,476,000 tons compared with 2,493,000 tons one week ago and 2,404,000 tons one year ago. Index of production for the week is 154.1.

November 6

▲ Eastern and Western railroads are seeking a 7 per cent emergency increase in freight rates to offset the wage advances granted November 1 and higher costs of materials. This petition is separate from the 15 per cent rate advances made to the ICC.

▲ J. L. Mauthe, president Youngstown Sheet and Tube Co., stated that his company expects capacity operations for the remainder of 1956 and estimates net profit at $11 per share for the year 1956 compared with $12.34 earned per share in 1955.

November 7

▲ Shipments of iron ore by the Lake Fleet last week amounted to 2,807,550 gross tons compared with 2,571,108 the previous week and 2,251,222 in the same period of 1955.

▲ The Commerce Department reported that wholesale sales declined in September to $10,500,000,000, down $60,000,000 from August.

November 8

▲ Kaiser Aluminum & Chemical Corp., announced that they plan to build an aluminum reduction plant by 1961 in Douglas County, Wash., if a Columbia River hydro-electric project survives a legal tangle and is completed.

▲ The Commerce Department reported an increase in business inventories in September 1956 to $86,300,000,000, $800,000,000 higher than August, and $6,600,000,000 above September, 1955. Sales were lower, dropping to $54,000,000,000, $1,300,000,000 under August, and $200,000,000 below September 1955.

▲ The Office of Defense Mobilization denied direct Government loans to industry for expanding nickel production, but announced, it will still grant permits for fast amortization for tax purposes and will enter into prime purchase contracts to aid nickel producers.

November 9

▲ Oil shipments to England and France were suspended at the request of the Arabian government because of severed diplomatic relations. Saudi Arabia concessions are owned by Arabian American Oil Co. and have been producing more than a 1,000,000 barrels of crude oil daily.

▲ Government figures showed that building expenditures in October amounted to $4,100,000,000, which was $200,000,000 below September, and $100,000,000 over October 1955.

November 9

▲ The Bureau of Mines reports that the consumption of scrap during September 1956 totaled 6,232,000 gross tons and pig iron 6,053,000 gross tons compared with 5,453,927 tons of scrap and 4,618,718 tons of pig iron in August.

November 10

▲ A 3-year agreement between officers of off-train unions affiliated with AFL-CIO and representatives of 140 carriers was reached granting wage increases of 26½¢ per hr. Settlement also states that no demands will be made for changes in compensation rules or new work rules for the period of the contract.

November 12

▲ American Steel & Wire division, U. S. Steel Corp., was forced to close down the Donora plant due to a strike of 78 employees of the Donora & Southern Railroad, who demand a fourth man be added to the crews of small diesel locomotives serving the open hearth shops.

▲ The AISI reports that the operating rate of the steel industry for the week of November 12 is scheduled at 100.4 per cent of capacity. This is equivalent to 2,472,000 tons compared with 2,463,000 tons one week ago and 2,394,000 tons one year ago. Index of production for the week is 153.9.

▲ Steel output in October climbed to 11,032,000 tons, 610,341 tons more than in September and 530,950 tons over October, 1955. Production for the first ten months of 1956 totaled 93,800,000 tons, down 2,400,000 from the same period in 1955.

November 13

▲ Granite City Steel will start construction of two new facilities at the cost of approximately $8,500,000. consisting of a sintering plant and two new batteries of soaking pits are underway.

▲ Charles L. Huston, Jr. president of Lukens Steel, predicted the company's sales will top $100,000,000 in 1956 with earnings of $20 or more a share. Sales

for the first 9 months of 1956 were $67,500,000 and profits equaled $13.40 a share.

November 14

▲ Monsanto Chemical Co., Inorganic Chemicals Div., announced an increase of $10 per gross ton in the price of ferrophosphorus, effective January 1, 1957, bringing the price of lump size ferrophosphorus in carload quantities to $110 a gross ton—other sizes and quantities are similarly increased.

November 16

▲ Frederick R. Kappel, president of American Telephone, announced company's plans for construction outlay of $2,500,000,000 for 1957, $300,000,000 over the 1956 outlay.

▲ Aluminium, Ltd. will invest approximately $100,000,000 in a French subsidiary to establish a new bauxite and alumina industry in French West Africa for raw material for its big aluminum expansion program in the Saguenaw District of Quebec.

▲ Ralph L. Gray, president of Armco Steel Corp., in an address before the Houston Society of Financial Analysis, indicated that some control on heavy exports of steel scrap may be necessary. He estimated exports would be nearly 5,500,000 tons in 1956, compared with 5,000,000 tons in 1955, and reported that foreign steel producers want even more next year.

November 18

▲ F. W. Dodge Corp. released estimates today stating that the dollar volume of construction awards in 1957 will total $20,393,000,000 for the 37 states east of the Rockies, an increase of 7 per cent over 1956, but that physical volume of construction would not rise as rapidly as the dollar volume due to rising construction costs.

November 19

▲ Deliveries of new domestic freight cars in October totaled 5666 cars compared with 3444 in September, 1956 and 3772 in October 1955. Orders in October totaled 6532 compared with 3949 in September. Backlog of cars on order as of November 1, 1956 stood at 122,250 cars.

▲ The AISI reports that the operating rate of the steel industry for the week of November 19 is scheduled at 99.8 per cent of capacity. This is equivalent to 2,458,000 tons compared with 2,466,000 tons one week ago and 2,416,000 tons one year ago. Index of production for the week is 153.0.

▲ President Eisenhower approved a program setting prices this country will pay for fissionable materials produced, up to June 30, 1963, in foreign reactors fired with U. S. atomic fuel. This program disclosed that atomic reactor fuel will be sold to foreign countries by the U. S. government at reduced prices in order to spur world-wide development of nuclear energy for peaceful uses.

November 20

▲ Construction contract awards in the 37 states east of the Rockies in October, according to the F. W. Dodge Corp., amounted to $1,706,406,000, a decrease of 8 per cent compared with October 1955.

▲ The Aluminum Association reports primary aluminum production in the United States during October, 1956 was 298,254,483 lb, compared with 264,631,718 lb in September, 1956 and 269,313,822 lb in October 1955.

▲ The Industrial Heating Equipment Assn. reported that orders for industrial furnaces during October amounted to $8,740,780 compared with $9,574,775 last year.

▲ A merger has been authorized by the board of directors of both Interlake Iron Corp. and Globe Metallurgical Corp., to become effective December 31, subject to ratification by Globe Metallurgical stockholders.

November 21

▲ Gasoline and diesel oil rationing will become effective in Britain on December 17, France cut diesel oil use to 80 per cent of September levels.

▲ Spokesmen in the Depts. of Commerce and Labor predict higher construction expenditures in 1957, probably up to a total $46,400,000,000 an increase of 5 per cent over indicated 1956 figures. Private houses to be started in 1957 are estimated at 1,000,000 units compared with 1,100,000 in 1956 and 1,300,000 in 1955.

▲ Shipments of machine tools in October totaled $89,000,000, an increase of 26 per cent over September, and brought the 10-month deliveries to $719,000,000 compared with a total of $670,000,000 for all of 1955. New orders in October fell to $66,000,000, compared with $78,000,000 in September, and $99,000,000 in October, 1955.

▲ Republic Steel Corp. declared a quarterly dividend of 75¢ on its common stock and put the stock on a $3 annual dividend basis.

▲ The board of directors of Crucible Steel declared a fourth quarter dividend of 75¢, called a special meeting of the stockholders to decide a proposed 2 for 1 stock split, and announced a rebuilding program, in addition to the $20,000,000 program now under way, to cost $25,000,000.

November 23

▲ A request for a 5 per cent increase in passenger fares, effective January 1, has been filed with the ICC by the Western railroads.

November 26

▲ The AISI reports that the operating rate of the steel industry for the week of November 26, is scheduled at 100.3 per cent of capacity. This is equivalent to 2,469,000 tons compared with 2,463,000 tons one week ago and 2,356,000 tons one year ago. Index of production for the week is 153.7.

November 28

▲ Resistance Welders Manufacturers Assn. reported October shipments by members of approximately $4,000,000 with backlog of members at October 31 at approximately $15,000,000.

▲ Steel scrap prices in Pittsburgh reached $67 a ton for No. 1 heavy melting scrap, and reflects an advance totaling $9 a ton on this grade.

▲ Price of refined copper for January delivery has been cut to 35½¢, down ½¢ by custom smelters, spot and December delivery prices are firm at 36¢ a lb.

▲ An extra dividend of $1.50 has been authorized by Lukens Steel Corp. bringing the 1956 payments to $6, compared with $2 last year.

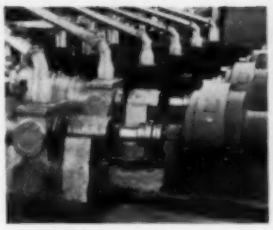
November 29

▲ The National Coal Assn. predicted that soft coal output in 1957 will increase to 532,000,000 tons, compared with an indicated 509,600,000 tons in 1956.

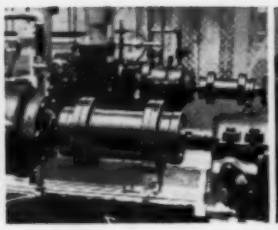
November 30

▲ Eugene G. Grace, chairman of Bethlehem Steel Co., announced that the directors had voted a four-for-one split on common stock, subject to shareholders approval at a special meeting January 17.

▲ Prices of hard coal by producers will advance 95¢ to $1.25 a ton effective December 1. This advance results from a raise in wages to miners of $1.50 to $2.00 daily, and follows two earlier price boosts, from 25 to 50¢ a ton in September and a 25 to 76¢ additional on November 1.

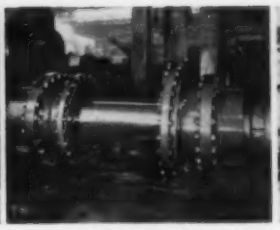


Paper Industry

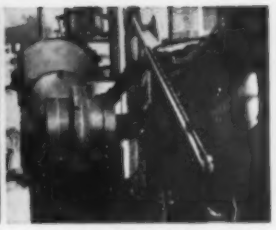


Oil and Gas Industry

Marine Industry

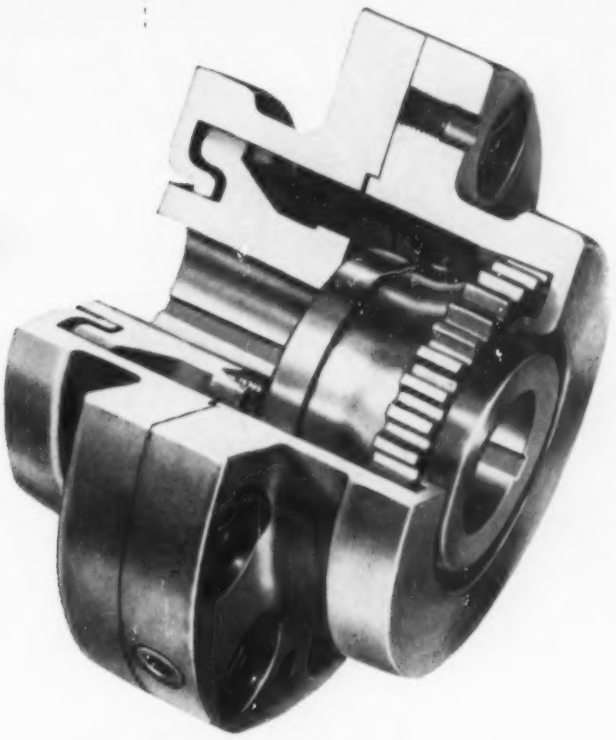


Steel Industry

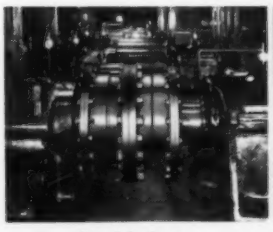


Oil and Gas Industry

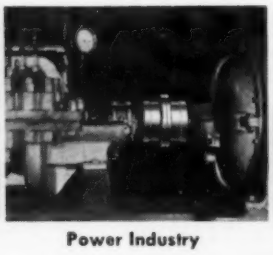
Why have Fast's Couplings always been the leader in the rugged steel industry?



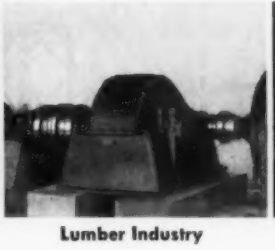
Why are they used so widely to couple machinery in Power Generation, Pulp and Paper, Oil and Gas, Marine Propulsion and Auxiliaries, Steel and industry in general?



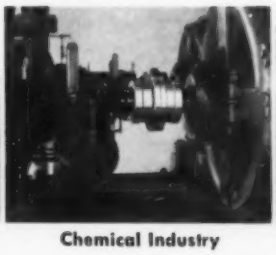
Steel Industry



Power Industry



Lumber Industry



Chemical Industry

Paper Industry

Fast's Couplings are standard equipment with more machinery manufacturers than any shaft coupling on the American market. Many Fast's Couplings in use over 30 years still show no signs of wear when disassembled! That's the answer: they're reliable, they're *mechanically* flexible, they don't wear. They have no parts subject to repeated bending, tension or compression. There is no metal-to-metal contact, because of *positive lubrication.* Regardless of your field—no matter whether your connected machine is driven by steam turbine or electric motor, low-speed diesel or high-speed gas turbine . . . Koppers has the perfect, low-cost solution to your shaft coupling problem.

For free catalog write to: KOPPERS COMPANY, INC., *Fast's Coupling Dept.,* 3012 Scott St., Baltimore 3, Md.

METAL PRODUCTS DIVISION • KOPPERS COMPANY, INC. • BALTIMORE 3, MD. This Koppers Division also supplies industry with American Hammered Industrial Piston and Sealing Rings, Aeromaster Fans, Industrial Gas Cleaning Apparatus, Gas Apparatus.

Engineered **Products Sold with** *Service*

KOPPERS

THE ORIGINAL

FAST'S Couplings

Twin Benefits from Mead-Morrison COAL UNLOADER

Greater Economy

because of Mead-Morrison's progressive reeving system

This system, originated by Mead-Morrison, utilizes a single continuous rope for both the hoisting and closing motions of the grab bucket. The rope is fed into the system from a storage reel in small increments to replace worn portions of the rope. By thus distributing the wear the rope is used more efficiently and a longer rope life is realized than is possible with any two-rope system.

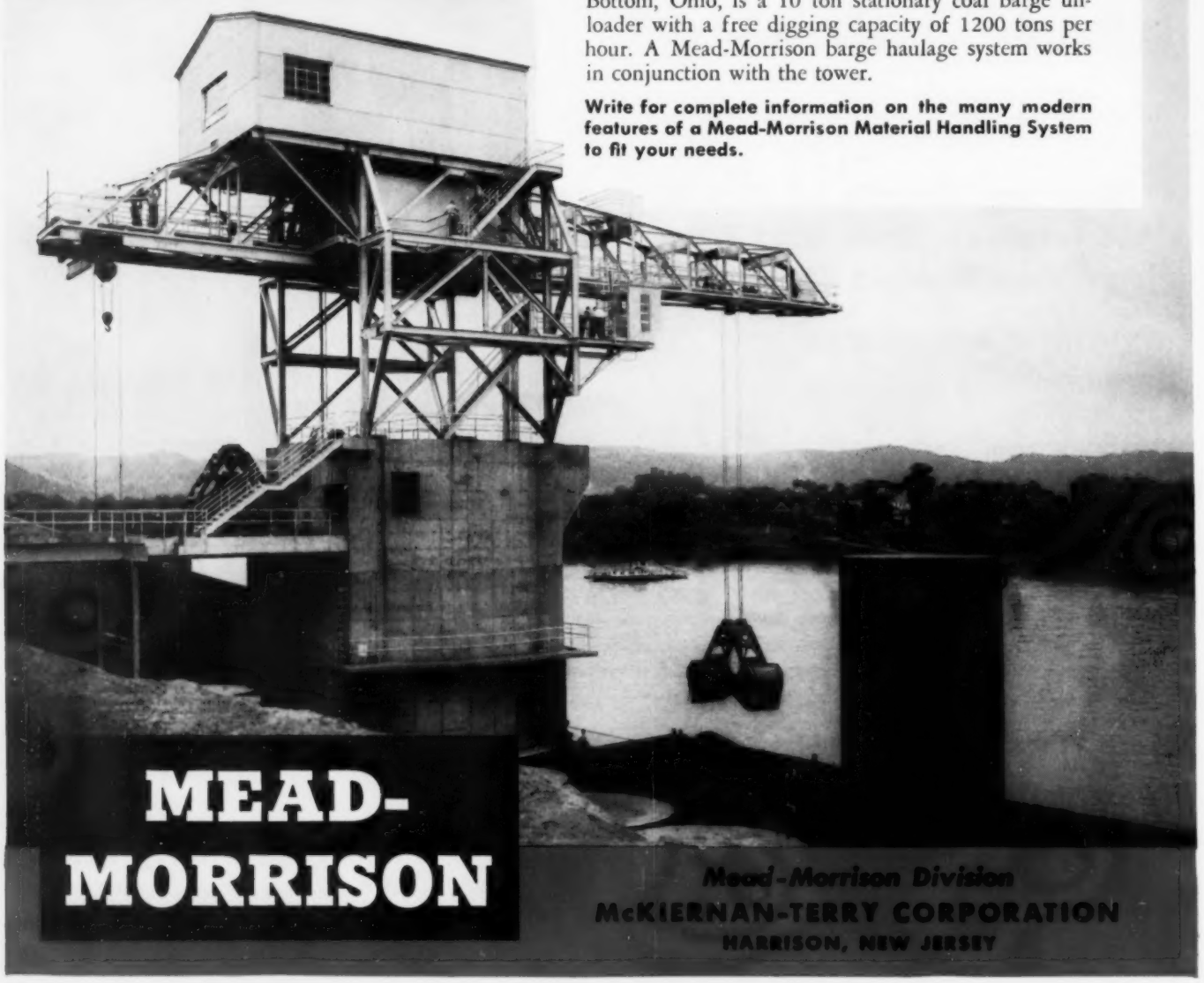
Greater Safety

because of Mead-Morrison's "dead man" control

All motions of the bucket are controlled by two short, latched levers. The operator is not forced to shift his hands from these levers at any time in the operating cycle. If the operator removes his hand from any lever for any reason, that motion is automatically stopped, thereby preventing uncontrolled motion.

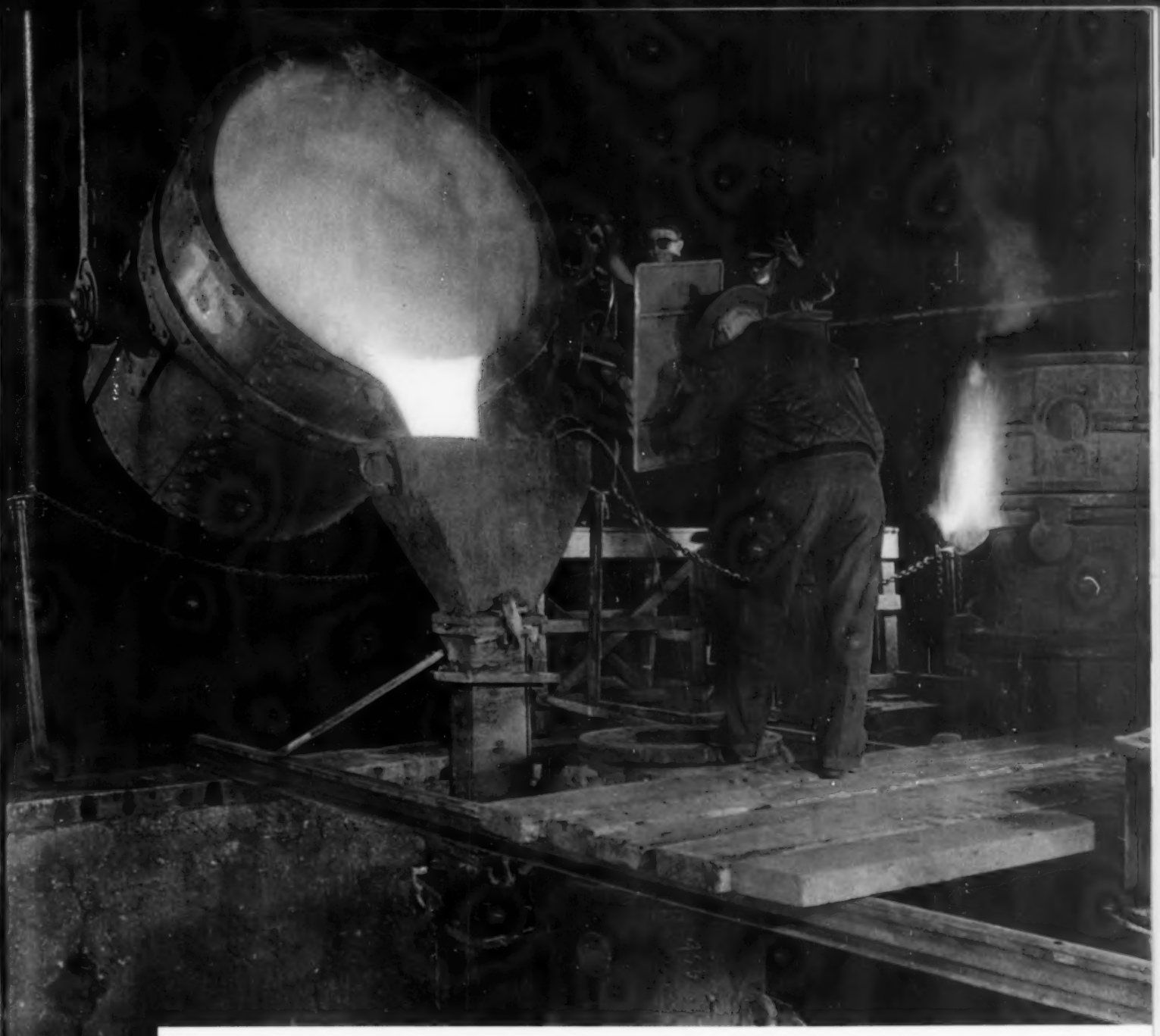
This Mead-Morrison Tower installed at the R. E. Burger Station of the Ohio Edison Company at Dilles Bottom, Ohio, is a 10 ton stationary coal barge unloader with a free digging capacity of 1200 tons per hour. A Mead-Morrison barge haulage system works in conjunction with the tower.

Write for complete information on the many modern features of a Mead-Morrison Material Handling System to fit your needs.



MEAD-MORRISON

Mead-Morrison Division
McKIERNAN-TERRY CORPORATION
HARRISON, NEW JERSEY



The man with the shield

During pouring, the future of a mill roll hangs in the balance. Its quality is wholly dependent, for the moment, upon the skill and experience of the pouring crew. All the metallurgy, all the hours of pattern making and painstaking mold preparation, all this rests on the shoulders of the man with the shield and the flawless execution of the orders he gives as he watches the molten metal swirl up from the bottom of the mold.

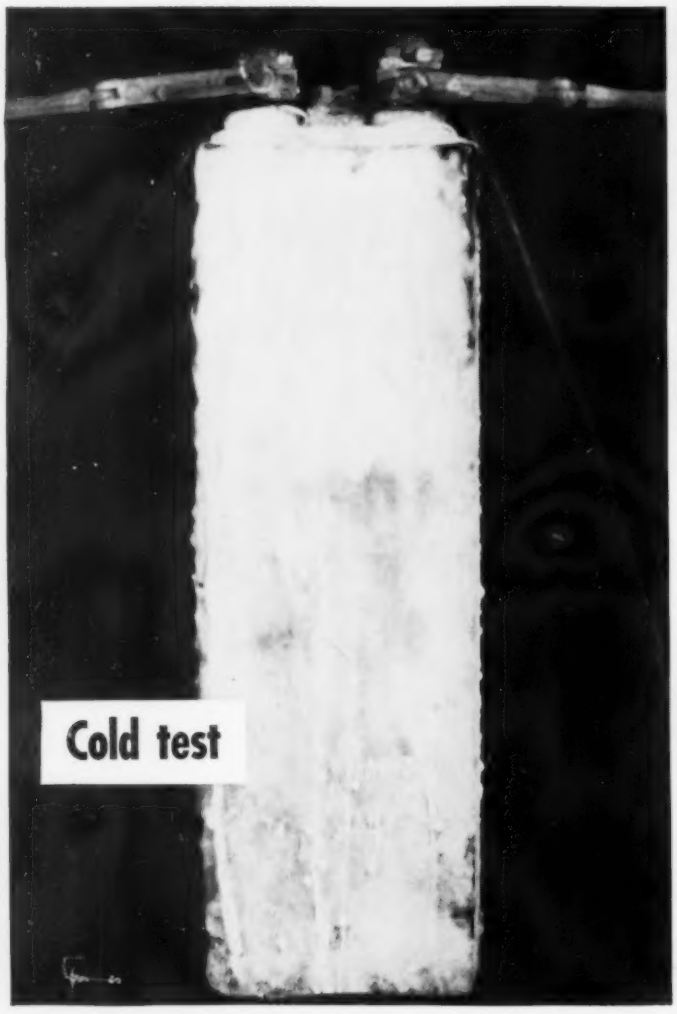
Mack-Hemp's pouring crews rank among the country's top foundrymen. Their ability is reflected in the quality of Mack-Hemp rolls, a quality that has been unmatched for more than one hundred and thirty years...an important reason why *you get more tonnage from the rolls with the Striped Red Wabblers.*

MACKINTOSH-HEMPHILL
Division of E. W. BLISS Company
Pittsburgh and Midland, Pa.

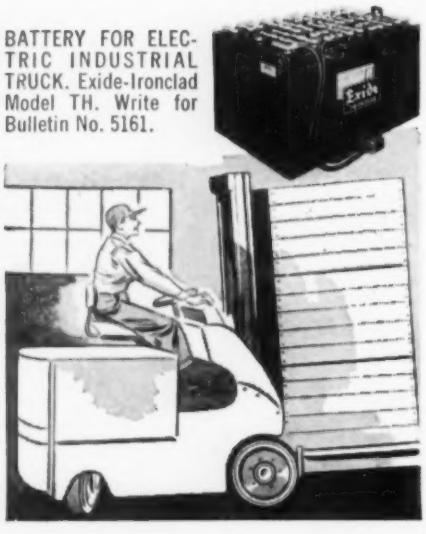
MACKINTOSH-HEMPHILL DIVISION · PITTSBURGH · U.S.A.
BLISS

EXIDE-IRONCLAD BATTERIES

For electric industrial truck operation



Deliver the power over a wide range of temperatures



BATTERY FOR ELECTRIC INDUSTRIAL TRUCK. Exide-Ironclad Model TH. Write for Bulletin No. 5161.

At few places on earth do storage batteries ever encounter such extremes of cold and heat as are used to test Exide-Ironclad Batteries in the laboratory.

These tests prove that Exide-Ironclad Batteries can be depended upon over a wider range of temperatures than they are ever likely to be asked to endure. And they provide tangible extra assurance of dependability at all the more normal operating temperatures.

Extreme temperature performance is especially important when a battery must have continuous dependability. It is often at these extremes that a battery is most needed. And a battery cannot be called dependable unless it can be counted on every day—all of the time.

The high and low temperature performance of Exide-Ironclad Batteries is a direct result of their unique construction features and special engineering. In countless applications, these batteries have earned an unmatched reputation for long life and high capacity. When you need batteries for heavy duty uses, be sure to specify Exide-Ironclad. Write for detailed bulletin. Exide Industrial Division, The Electric Storage Battery Company, Philadelphia 2, Pa.

Exide®

CONTINUOUS THERMAL PROCESSING...

more steel... improved quality!

A significant first in the steel industry has resulted from the recent installation of three new and identical annealing lines, each designed to deliver 20 tons of improved-quality silicon steel per hour.

This continuous annealing operation in a limited area created an unusual problem in control accuracy and reliability. Westinghouse MAGAMP* magnetic amplifier regulators form the heart of the control system . . . make this the first all-magnetic amplifier continuous annealing line. Westinghouse furnished complete electric equipment and furnaces for all three lines.

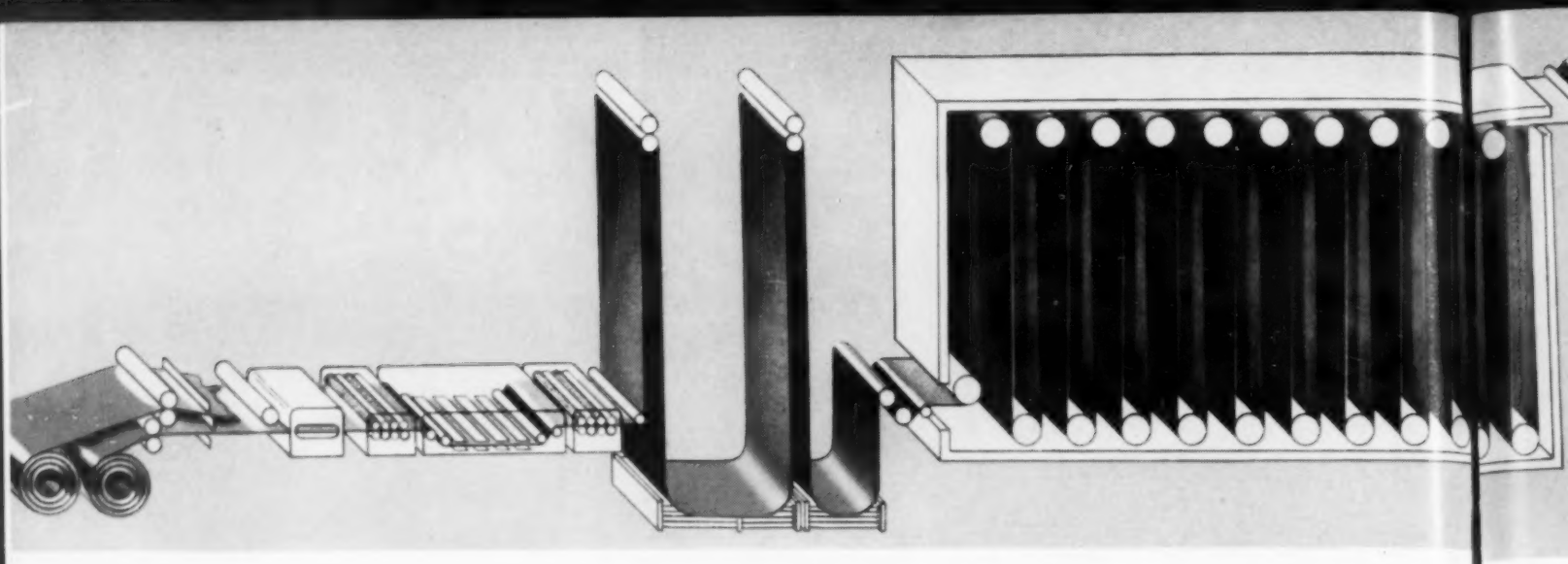
And . . .

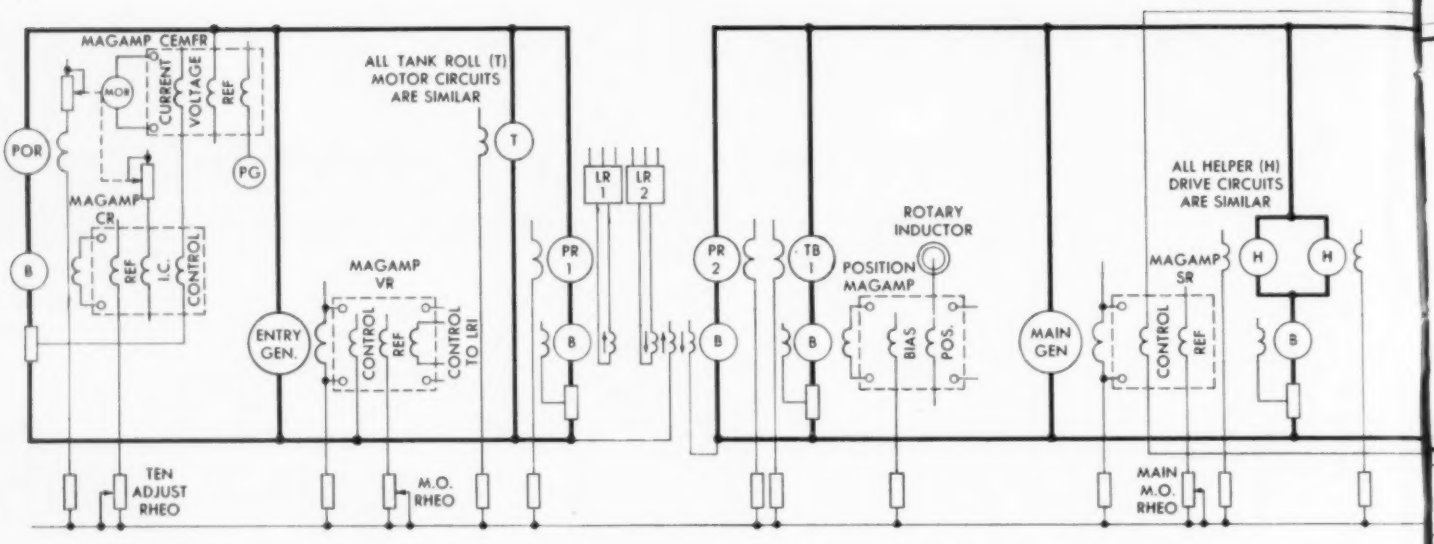
Here's another big development in the steel industry ———

*Trade-Mark

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING **TODAY!***





Tin-plate annealing equipment designed for . . .

Process speeds beyond 2000 fpm, output 60 tons per hour!

Tin-plate annealing lines now being built will be capable of boosting output as much as 100% over existing continuous lines.

Continuous annealing lines are from 300 to 400 feet in floor length. Since the strip travels through many vertical passes, several thousand feet of tin plate are accommodated in the line between the pay-off and winding reels.

High-speed annealing operations like this demand the ultimate in coordination and reliability. Westinghouse motors, controls, furnaces and related equipment will help you handle speed and output up to and beyond 2000 fpm, 60 tons per hour—while maintaining precise quality standards. Moreover, Westinghouse accepts full unit responsibility for the electric and furnace equipment installed in your line.

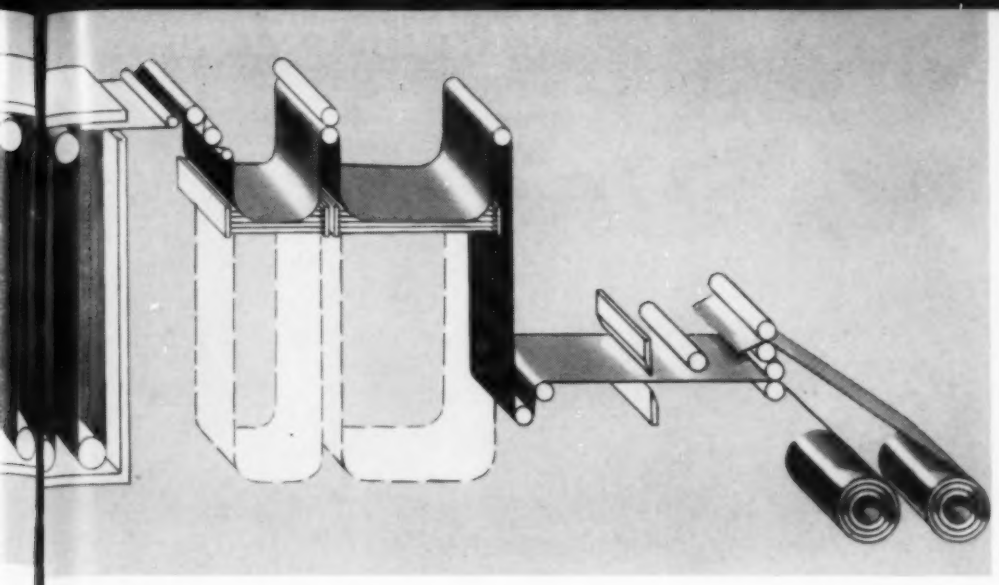
How Line Control Operates

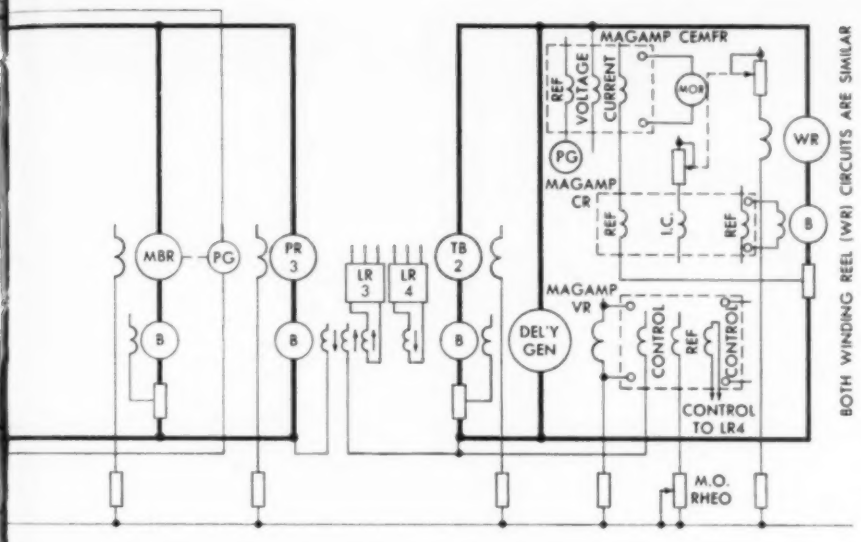
Westinghouse has many years of successful experience applying MAGAMP regulators to drive systems. Above diagrams show how Westinghouse MAGAMP regulators are applied in modern, continuous annealing lines.

MAGAMP speed regulator (SR) maintains constant speed through the critical annealing zone. Speed reference, set by main motor-operated rheostat (MOR), is

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING **TODAY!***





balanced by the control winding fed from the pilot generator (PG) driven by the master bridle roll (MBR).

MAGAMP voltage regulators (VR) control the voltage of the entry and delivery generators assuring fast, even acceleration and deceleration and a minimum of loop disturbance during steady operation. Loop regulators set as verniers in controlling generator voltages.

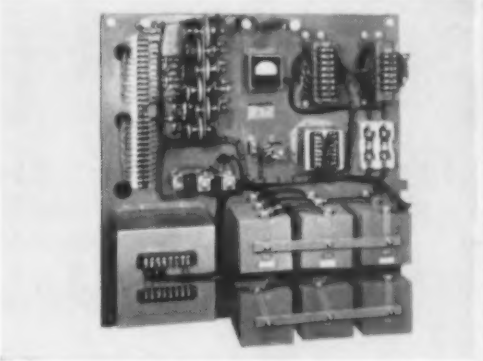
MAGAMP current regulator (CR) for booster, and MAGAMP counter-EMF regulator (CEMFR) for motor, work together so regulated tension is maintained by the pay-off reels (POR) and winding reels (WR). Inertia compensation (IC), proportional to accelerating loads, and stall tension signals are introduced through the (CR) circuits.

Photo-thyratron loop regulators (LR) provide modulated control of storage loops for smooth operation.

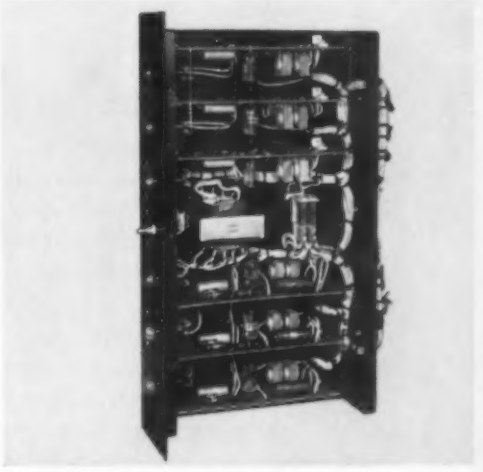
Machine characteristics are selected for best drive performance. Pinch roll no. 1 (PR-1), master bridle roll (MBR), and tension bridle no. 2 (TB-2), the pacesetters of their respective line sections, are shunt-wound for flat, speed-load characteristic. Helper drives (H) have high drooping characteristics which result in their developing only the power required to overcome their friction losses and inertia loads. Reel motors have high overload capacities suitable for accelerating the large coils which are now used in most mills.

MP-3044

Centralized line control reduces space requirements and provides ready accessibility for inspection.



Magamps bring outstanding precision, dependability to line control . . . no moving parts, brushes, commutators, bearings.



New Westinghouse fault finder monitors control circuits simultaneously, indicates faults instantly and makes trouble-shooting easy.

Westinghouse d-c motors perform efficiently under tough conditions. High starting torque ideal for high inertia loads.

Westinghouse continuous furnace anneals eight tons per hour of silicon steel at 184 fpm and stress relieves 20 tons per hour at 460 fpm.

Three ways Westinghouse furnaces match increased annealing speed

Westinghouse gas and electric furnaces meet the demands of today's high-speed thermal processing and annealing lines three ways:

Construction—furnace layout compensates for thermal expansion. Maximum accessibility provided for convenient replacement of burner and heating element panels and rethreading.

Temperature Control—Typical examples are: proportioning-type controls to regulate recuperative radiant tubes in gas-fired furnaces; Furnatron® regulators to maintain constant temperatures in electric furnaces.

Atmosphere—Westinghouse atmosphere generators provide controlled and protective atmosphere which maintains product quality at higher speeds. Strip is produced flatter, more uniform . . . surface is cleaner.

Westinghouse consulting, application and design engineers can speed equipment installation, eliminate problems right from the start. They help match correct products to the job, test them to assure proper operation.

From planning or problem, to design, installation and start-up . . . Westinghouse is at your service. An experienced Westinghouse team will work with your engineering staff and consulting engineers in setting up your thermal process line.

For your convenience . . . 38 manufacturing and repair service plants superbly equipped for repairing all types of electric apparatus . . . 34 renewal parts warehouses strategically located in industrial centers, open 24 hours a day.

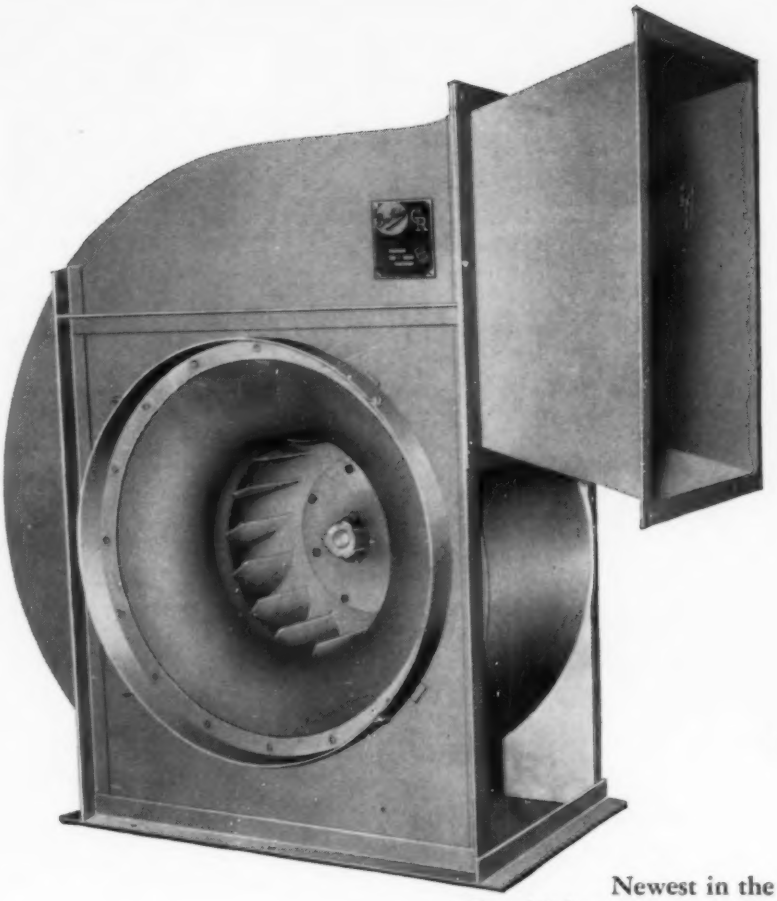
Contact your Westinghouse sales office for further details. Ask for a copy of B-6072, *Westinghouse Drives for Processing Lines.* Or write, Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania. MP-3044

Completely self-adjusting, magnetic, d-c motor brake assures safer, more positive stops and starts. Maintenance and replacements minimized.

Westinghouse engineers help you plan installations like this compact a-c control center for fans, pumps and other auxiliary equipment.

WATCH WESTINGHOUSE!

WHERE **BIG** THINGS ARE HAPPENING **TODAY!**



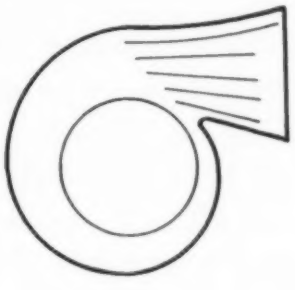
NEW

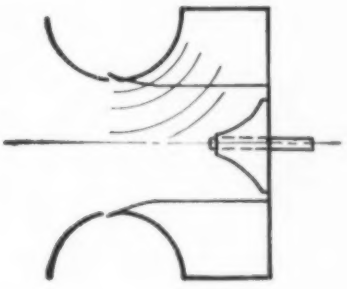
"BUFFALO" TYPE "CR" RADIAL BLADE FAN

Engineered for Your High-Volume High-Pressure Jobs

Newest in the complete line of "Buffalo" Fans, the Type "CR" offers high mechanical efficiency (above 78%) over a broad range, and has high-pressure, high-volume characteristics that make lower first cost possible on many applications. It is also highly suitable for handling dust-laden air efficiently.

In the illustration of the "CR" wheel, you will note the deeply pressed, curving flange. It provides rigidity and meets the curved inlet bell to form a true half-circle air entry path into the wheel (shown in cross section diagram). Wheel blades are radial at tip, curving smoothly forward at inlet. The streamlined housing with divergent outlet further minimizes abrasive effects and aids efficiency by reducing turbulence. While "Buffalo" builds other type fans of higher efficiency than the "CR", its highly desirable balance of favorable first cost, high efficiency and long life assure substantial overall savings in heavy industrial service. Write for new Bulletin FD 205 and see the "Q" Factor* features built into this quality fan.





**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

BUFFALO FORGE COMPANY

BUFFALO, NEW YORK

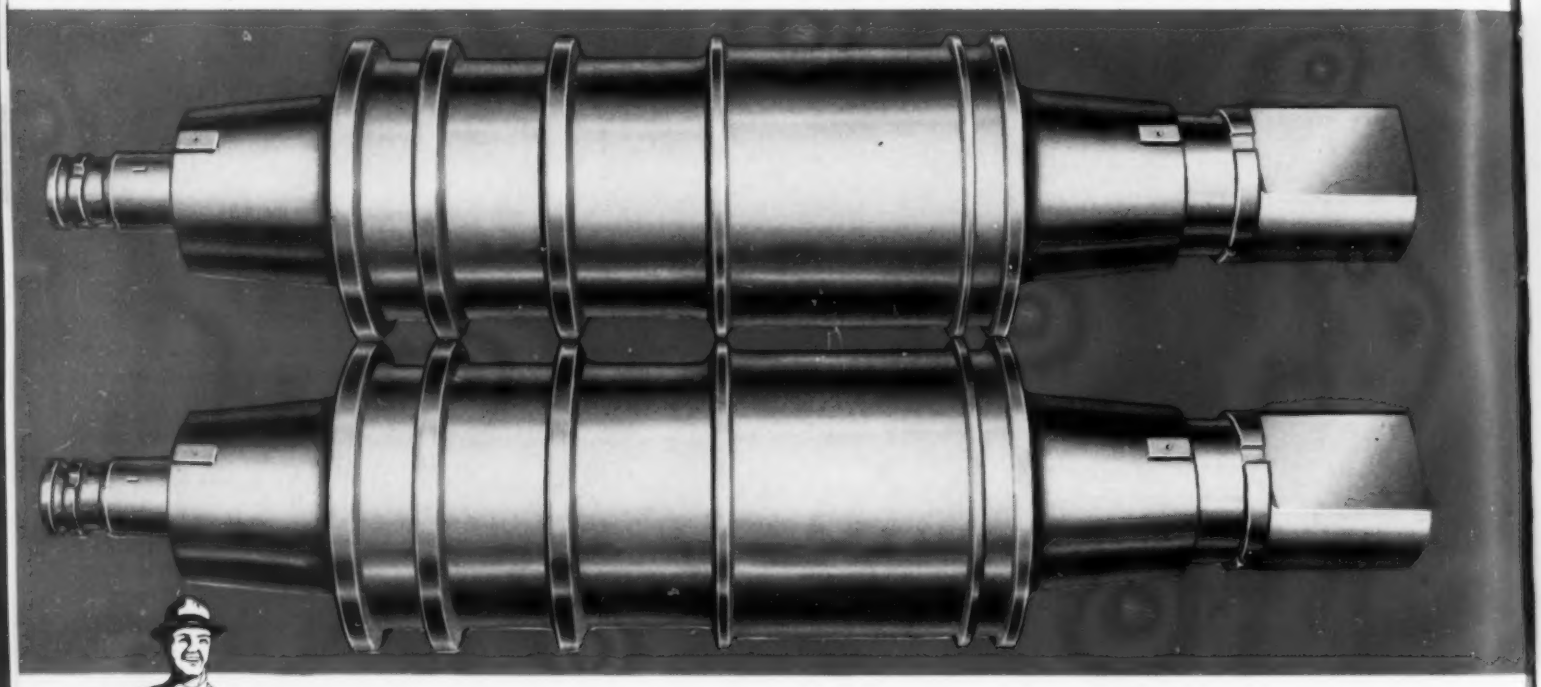
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo"

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

Ohio Rolls

correct roll design—
rigid quality controls—
where roll life begins!



The service life of Ohio Rolls begins with integrated planning by a group of specialists analyzing roll requirements . . . Ohio's designers—metallurgists—chemists —engineers—foundrymen—and inspectors . . . working directly with *your* Ohio Roll Representative. Their job is to make sure that Ohio Rolls meet rigid job specifications—in design, metal analysis, hardness, tensile strength, dimension and finish. These are operations that require specific planning to make certain that Ohio Rolls deliver High Tonnage . . . give Long Life . . . and Satisfactory Service.

OHIO ROLLS SERVE THE WORLD

When you need rolls—large or small—call in your Ohio Roll Representative. He understands production requirements, and he can help you solve your roll problems quickly and efficiently.

shaping metal for all industry

Carbon Steel Rolls	Ohio Double-Pour Rolls	Nickel Grain Rolls
Ohioloy Rolls	Chilled Iron Rolls	Special Iron Rolls
Ohioloy "K" Rolls	Denso Iron Rolls	Nioloy Rolls
Flintuff Rolls		Forged Steel Rolls

THE OHIO STEEL FOUNDRY COMPANY

LIMA, OHIO

Plants at Lima and Springfield, Ohio

ORS

Industry News...

RECORD MONTHLY OUTPUT SET BY ARMCO PLANT

▲ The Middletown Works of Armco Steel Corp. produced more steel ingots and more pig iron in October than in any other month in its history, according to an announcement by G. D. Tranter, Works Manager.

The plant's 13 open hearth furnaces and two electric furnaces turned out 189,217 tons of ingots during October. The best previous month in the plant's history was last April when 186,421 tons of ingots were produced.

During October, the three blast furnaces also broke all records with a combined production of 107,365 tons of pig iron. The previous record month was May of this year when 106,559 tons were produced.

Monthly records were smashed by the Middletown and Hamilton No. 2 blast furnaces. Middletown furnaces produced 54,107 tons of pig iron in October, compared with 52,683 tons in September, the previous record month. Hamilton No. 2 blast furnace turned out 30,589 tons; its previous record month was last May when production reached 30,017 tons.

GRANITE CITY TO ADD OXYGEN GENERATOR

▲ A generator to produce oxygen by the liquefaction of air will be built at the Granite City Steel Co. next year by Air Products Co.

The generator will be able to produce 70 tons — 48,000,000 cu ft — of oxygen a month. The company already operates two smaller oxygen generators.

BLAW-KNOX AWARDS CONTRACT TO DRAVO

▲ Dravo Corp. has been awarded a contract by Blaw-Knox Co. for four Dravo-DeLaval mill lubrication systems for installation on rod mill equipment in the plant of the Keystone Steel and Wire Co., Peoria, Ill.

A custom designed system providing a 230 gallon per minute flow of 2400 SSU oil at 100 F will lubricate 11 pinion stands and drives of a 23-stand mill. A second system providing 76 gal per minute of the same grade oil will lubricate another six stands. The balance of the stands and six laying reels will be lubricated by a 130 gal per minute, 2400 SSU at 100 F, system. Four pouring reels will be equipped with a Dravo-DeLaval Unilube "package" system providing a 30 gal per minute flow of 2400 SSU at 100 F.

CURTAIN WALL CONSTRUCTION OPENS NEW MARKET

C. F. Hood, president of United States Steel, and D. J. McDonald, president of United Steel Workers, CIO, teamed up recently to install the last stainless steel panel to go into the Homestead District Works new general office building. The photograph shows the building as it will appear when ready for occupancy in March, 1957. This is believed to be the first stainless steel curtain wall office building ever built, and also the first to use porcelain enamel sheets in the size used on the back of the building. These were 4½ ft wide by 12 ft high. One of the advantages of this curtain wall construction is that they provide a rapid and inexpensive means for erection; and, in addition, the thinner walls give increased floor space, lighter dead loads, and lower foundation costs. In this U. S. Steel office building, savings in floor space were equivalent to a 20 x 40 ft office on each floor. The front and sides of the building have stainless panels 4 ft-6 in. wide, 12 ft 2½ in. thick at the edges. Stainless is 24 gage which is backed up by 1¼ in. thick fiberglass insulation, and the interior surface is 14 gage cold rolled steel sheet. The procelain panels are 1½ in. thick and are a 14-gage vitrenamel sheet on the exterior and have a 14 gage cold rolled steel sheet on the inside. Their cost is somewhat less than the stainless panels and they offer an architect a wide range of colors.

ANNOUNCES ACQUISITION OF SENDZIMIR INTERESTS

▲ The Waterbury Farrel Foundry & Machine Co. of Waterbury, Conn. has acquired the Sendzimir Cold Rolling Mill interests of the Armzen Co., according to a joint announcement by Mr. A. D. Mitchell, president of Waterbury Farrell and Mr. T. Sendzimir, president of Armzen.

This portion of Armzen interests will be incorporated into Waterbury Farrel's operating structure as a new division, to be known as the Sendzimir Mill Division with Mr. T. Sendzimir as manager. It will be staffed by the present Armzen Co. personnel and will handle sales, engineering and servicing of Sendzimir cold sheet and strip mills.

During the past 15 years, the Waterbury Farrel Foundry & Machine Co. has been the principal manufacturer of Sendzimir cold rolling mills under license from the Armzen Co. which handled the sales, engineering and servicing functions.

ANSWERS to YOUR Refractory and Insulation PROBLEMS *in these New Bulletins*

SUPER #3000
Refractory Cement

Technical and performance data on the truly superior bonding, lining and patching mortar for blast furnace linings, sintering tower linings, soaking pit covers and recuperator tubes, electric melting furnaces, reheating furnaces, coke ovens, etc. Strongest and most durable of all plastic refractory materials; most resistant to erosion, abrasion and spalling at all temperatures to 3000° F.

MOLDIT
Castable Refractories

Complete physical and service data on 12 different Moldits and their respective applications for back-up linings for blast furnaces, soaking pits and ladles; hot top molds; sealing open hearth furnaces, reheating furnaces, interiors, car tops, piers and covers, stack linings, coke oven linings, etc.

R & I INSULATIONS

Physical and thermal characteristics, application and how-to-use helps on Insulating Block, Mineral Fiber Blankets and Stic-Tite Plastic Insulation for air heaters, hot air, ducts, hot blast stoves, open hearth regenerators, reheating and annealing furnaces, ovens, steel stacks, etc.

The answers to your need for reducing refractory maintenance and improving heat economy are in these bulletins. They're yours FREE for the asking. Write today.

REFRACTORY & INSULATION CORP.

REFRACTORY BONDING AND CASTABLE CEMENTS
INSULATING BLOCK, BLANKETS AND CEMENTS

136 WALL STREET • NEW YORK 5, N. Y.

TO PRODUCE NUCLEAR GRAPHITE IN ENGLAND

▲ The organization of Anglo-Great Lakes Corp. Ltd. for the production in England of nuclear and commercial graphite has been announced by Great Lakes Carbon Corp. British companies joining in the enterprise are C. A. Parsons & Co. Ltd., A. Reyrolle & Co. Ltd., Sir Robert McAlpine & Sons Ltd., and Clarke, Chapman & Co. Ltd.

Construction of a plant at Newcastle, England will begin in the spring of 1957, with full production scheduled for late 1958. Initial capacity of the plant will be 15,000 long tons per year, with priority given to atomic energy requirements.

Nuclear-grade graphite is produced from petroleum coke and is used as a moderator in atomic reactors. Anglo-Great Lakes Corp. will provide a major source of graphite for Britain's nuclear power development program, now being pushed by private industrial groups in collaboration with Britain's Atomic Energy Authority.

OPENS BRANCH OFFICE AT ALLENTOWN, PA.

▲ A branch office has been opened by Allis-Chalmers Industries Group at 508 Turner Street, Allentown, Pa., under the management of Ralph L. Haney.

The new office is a branch of the Philadelphia district and will serve Berks, Lehigh and Northampton counties in Pennsylvania.

WARNER CO. APPOINTED PARKER REPRESENTATIVE

▲ Appointment of Warner Co., 3625 East 48th Ave., Denver 16, Colo., as distributor for Parker Appliance Co.'s tube and hose fittings and tube-working tools is announced by D. A. Cameron, general sales manager of Parker.

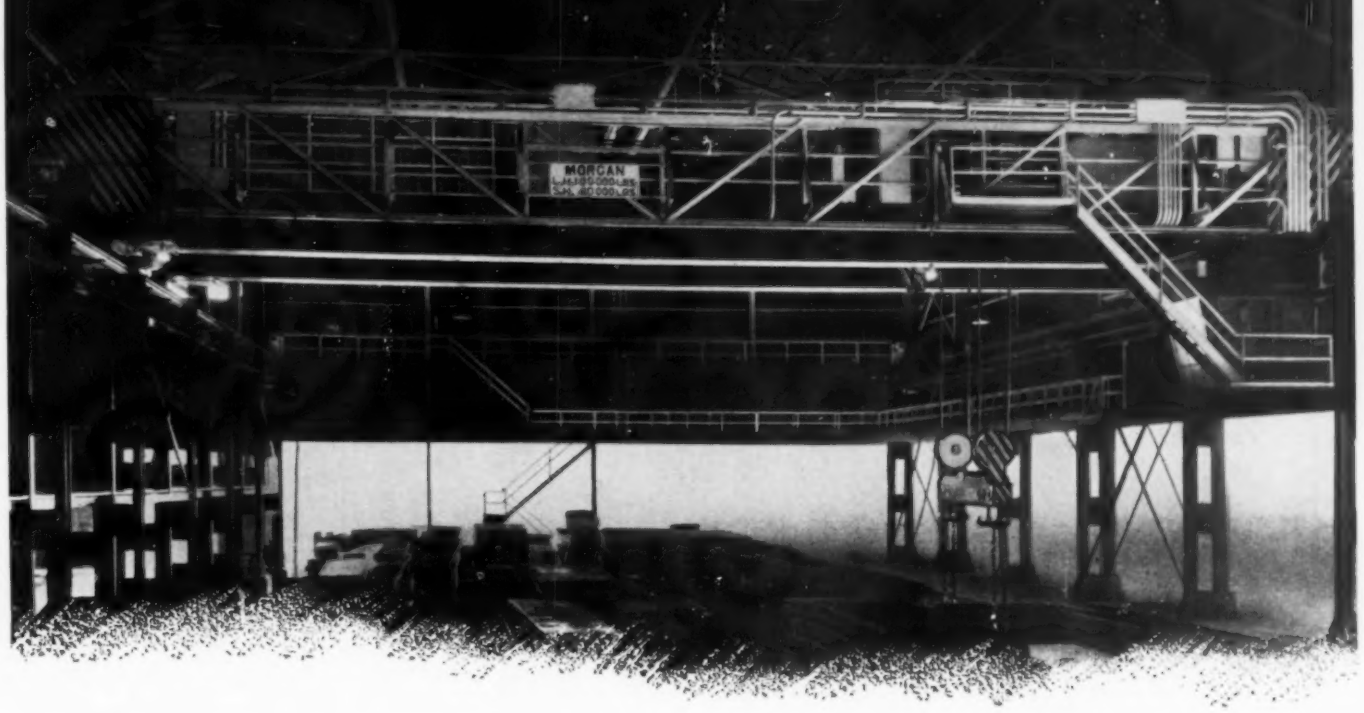
The distributing firm will carry stocks to service the Colorado area.

BROWN FINTUBE CO. FORMS NEW SUBSIDIARY

▲ Formation of a subsidiary to be known as the Brown Thermal Development Co. has been announced by Brown Fintube Co.

QUALITY AND PERFORMANCE

Two reasons why steel men specify Morgan cranes!

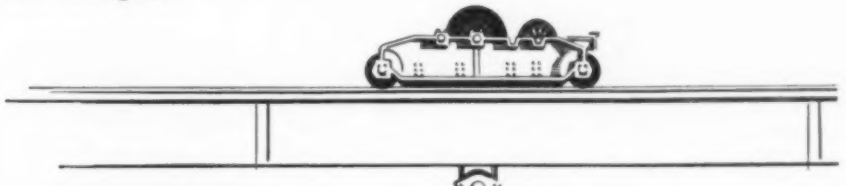


One of two Morgan 50/20 ton, 6-motor, 85' span, special double hoist, heavy duty mill type, slab-handling cranes recently installed in Eastern steel mill.

• Performance records prove conclusively that advanced design and heavy-duty construction of Morgan cranes make them less costly to operate and maintain.

These slab-handling cranes, recently installed in a new Eastern mill, were specified because of the features that make Morgan cranes best in the business.

You get this same performance in all steel mill equipment built by Morgan. The next time you buy equipment, let a Morgan representative show you how to save the most by buying the best . . . Morgan!

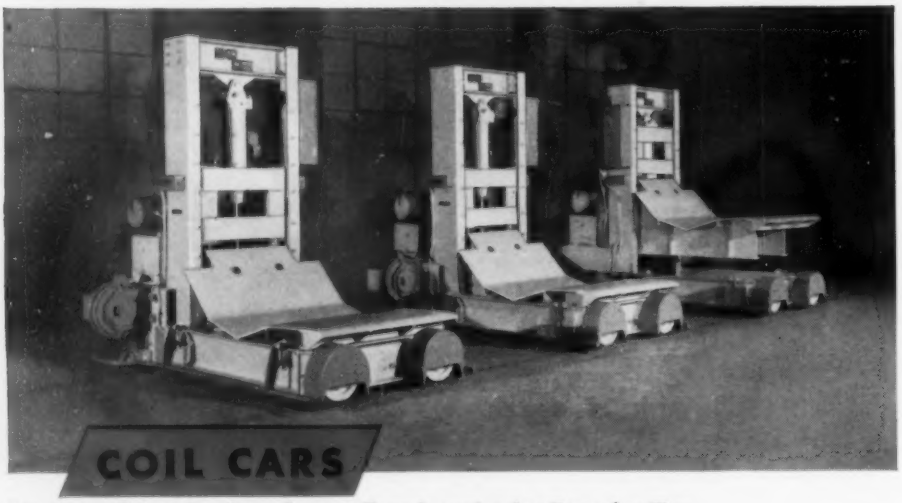


THE MORGAN ENGINEERING CO. *Alliance, Ohio*

The Morgan Engineering Company, founded in 1868, manufactures overhead electric traveling cranes, gantry cranes, open hearth special cranes, plate mills, blooming mills, structural mills, shears, saws, and auxiliary equipment.

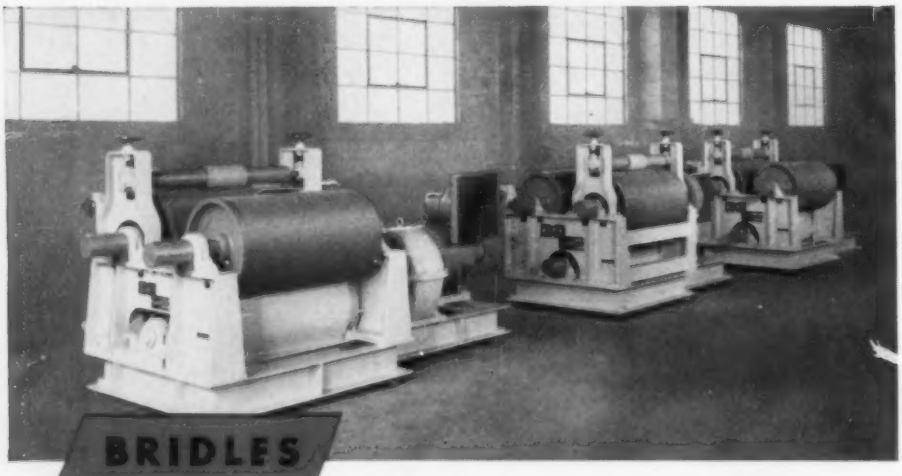
HERR EQUIPMENT

"Complete Processing and Handling Equipment . . . for any Ferrous or Non-Ferrous Material . . . That Starts — or Ends — as a Coil"



COIL CARS

For fast, efficient loading of pay-off reels and unloading of coiling reels. Sizes to handle coils of any diameter, width or weight. Hydraulic lift, electric traverse. No pits. Can be fitted with coil ejector, up-ender and other accessories if desired. Furnished complete ready for use.



BRIDLES

Types and sizes to meet any requirement. Plain steel, rubber covered or "Lorig" type self-aligning rolls. Air operated or regenerative brakes. Also four roll type that permits pay-off and coiling reels to be placed at the same end of the line and controlled with a single operator.

Write for fully descriptive Bulletin No. 561 today!

THE HERR EQUIPMENT CORPORATION

1270 VINE STREET • WARREN, OHIO

CLEVELAND, INDIANAPOLIS AND BERKELEY, CALIFORNIA

The new company will develop, design, manufacture and sell heat transfer equipment for waste heat recovery, recuperation, and air and gas heating by direct fire. The Fired Heater Division of Brown Fintube will be incorporated within the Brown Thermal Development Co.

COMPLETES RELINING OF CANTON FURNACE

▲ One of the fastest complete blast furnace relinings in the history of the steel industry was completed December 5 when the Canton, Ohio, blast furnace of Republic Steel Corp. was relighted after only 32 days of lost production. The furnace, which has a rated capacity of 680 tons of iron a day, was relighted by Lowell M. Immel, divisional superintendent of the Canton steel plant.

When the Canton blast furnace was last relined in 1948, 42 days were required to complete the job. This was a Republic record up to that time. Republic's Cleveland steel plant now holds the company record, relining its No. 3 blast furnace in 31 days.

A crew of 254 Republic employees and those of outside contractors carried out the relining under the direction of Paul L. Walter and William O. Fitzke, superintendent and assistant superintendent respectively of the plant's mechanical department.

Besides relining the furnace, additional work was done to put the blast furnace into first-class condition. More than 50 per cent of the checker bricks were replaced in two of the furnace's three heating stoves, the hot blast main and bustle pipe were relined and maintenance repairs were made to the furnace's auxiliary equipment. Cost of the blast furnace relining is in excess of one million dollars.

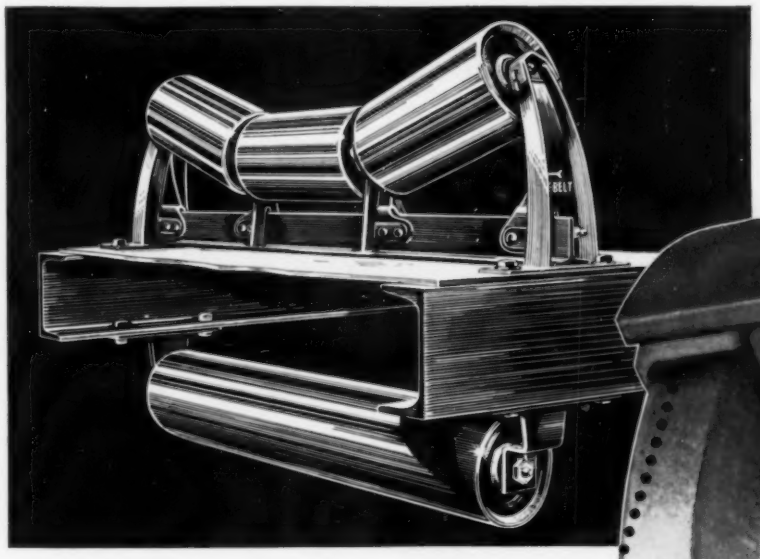
J&L DIVISION OPENS NEW TULSA FACILITIES

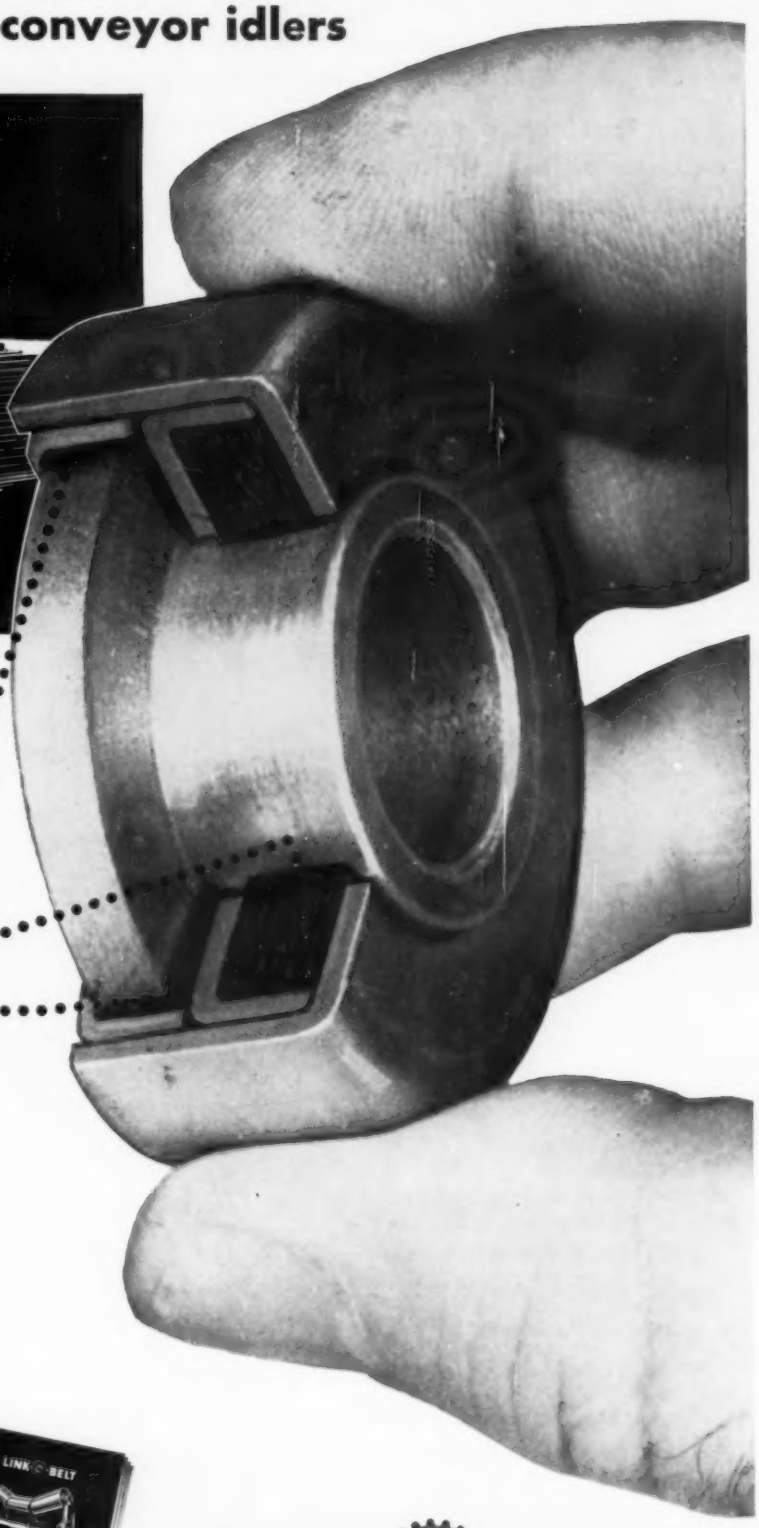
▲ Jones & Laughlin Supply Division formally dedicated its $1,700,000 headquarters building and supply store at Tulsa, Okla., on December 5. Admiral Ben Moreell, Chairman of the Board of J&L, officially opened the building by cutting a strand of J&L Wire Rope.

From its general office headquar-

TRIPLE DIRT DEFENSE

...yours in LINK-BELT belt conveyor idlers





this grease seal is 3 seals in 1

- **Labyrinth seal**
- **Contact seal**
- **Grease-filled clearances**

This compact, one-piece cartridge — a Link-Belt exclusive — is industry's simplest and most effective seal. Its three-way protection holds grease in, keeps dirt out for long bearing life. What's more, inspection and maintenance are simplified. No springs, clips and other small parts to lose . . . no metal-to-metal contact.

This superior seal is one of many long-life Link-Belt features. Others:

- *husky, high quality bearings*
- *precision-machined concentric rolls*
- *strong, rigid frames*
- *convenient grease fittings*
- *precision shaft-to-shell assembly*

These features are standard in most Link-Belt idlers . . . industry's only comprehensive line. For details on specific series, call your Link-Belt office or authorized stock-carrying distributor. Or write for Book 2416.

LINK-BELT

BELT CONVEYOR IDLERS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 14,238

POOLE

CURVED TOOTH COUPLINGS FOR GREATER MISALIGNMENT

We are now equipped to furnish on special order, couplings up to and including size No. 12 with curve-sided hub teeth, permitting misalignment up to plus or minus 5°.

This feature solves many problems where excessive misalignment becomes unavoidable, such as coupling arrangements which necessitate changing centers of rolls etc., or any sort of drive requiring more than the standard plus or minus 1°.

The method by which this is done represents the very latest gear cutting process. Gear teeth cut by this amazing and ultra modern method are not only to a precise and absolutely true shape, but are also generated to tolerances of astounding accuracy.

Engineers and draftsmen, when confronted with coupling problems involving more than the usual amount of misalignment, are invited to submit such problems to us for recommendation to suit their exact requirements.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY 1700 UNION AVE. BALTIMORE 11, MD.

ters in Tulsa, the division now directs the operations of 27 district and sales offices and 90 oil field supply stores in 17 states and three provinces in Canada.

These stores and offices serve the petroleum industry from the Rocky Mountain Divide to the Atlantic Coast, and from the Gulf of Mexico to the oil fields of Canada.

BREAK GROUND FOR NEW ARMCO DRAINAGE PLANT

▲ Ground has been broken in Springfield, Ill., for a new fabricating plant for Armco Drainage & Metal Products, Inc.

Armco has operated a fabricating plant in the Springfield area for more than 30 years, beginning with its purchase of the old W. Q. O'Neall Co.

The Springfield plant is one of four Armco Drainage plants in the Great Lakes Division, which covers Ill., Ind., Mich., and Wis. K. C. Thomas is Division Manager with headquarters in South Bend, Ind.

Armco Drainage also is in the process of building a new fabricating plant at Denver, Colo. and a plant at Atlanta, Ga.

U. S. STEEL ORE BOATS TO EXTEND SEASON

▲ Barring heavy ice conditions, ore carriers of Pittsburgh Steamship Division will break a 57-year fleet record for the latest Great Lakes shipping season in history, according to to Donald C. Potts, president of the United States Steel Corp. division. The previous record was set on December 17, 1899, when the STR. MALIETOA took on the last cargo of ore for the season at Two Harbors, Minn.

At the same time, Mr. Potts also revealed that the United States Army Corps of Engineers has approved continuing operations of the Soo Locks beyond December 15, the approximate date previously set for closing the St. Marys Falls Canal and Locks.

If weather permits, approximately 50 carriers of the 57-ship Pittsburgh Steamship fleet may continue hauling ore this season as late as January, Mr. Potts estimated.

"The movement of ore since we

(*Please turn to page 184*)

TIMKEN Company ORDERS 2 MORE DIAMOND ITV UNITS

(WIRED TELEVISION)

AFTER 3 SUCCESSFUL INSTALLATIONS

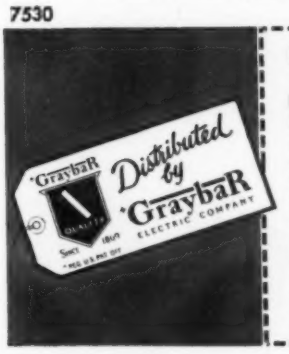
Picture of furnace interior on Diamond ITV viewing screen is watched by remote dispatcher. A flip of a switch and he SEES conditions in another furnace on same screen.

Operator at another control pulpit SEES a visually inaccessible billet loading area for a pusher type furnace.

The Timken Roller Bearing Company made its first application of Diamond Industrial TV in August 1951 for remote observation of the interior of a tube-cooling furnace. Since that time two additional installations have been made to watch (1) the inside of another furnace and (2) the remote handling of billets by a crane. The success of these has resulted in a recent order for two more sets of Diamond ITV.

You, too, probably can use Diamond ITV to substantial advantage. Call your Graybar Distributor or use the coupon below.

7530



DIAMOND POWER SPECIALTY CORP.
"FIRST IN INDUSTRIAL TELEVISION"
ELECTRONICS DEPT., P. O. BOX 56VV
LANCASTER, OHIO

Please send me without obligation a copy of new bulletin showing how Diamond Industrial (Wired) Television will help me reduce costs, improve quality, increase sales and aid safety.

Name_____

Title_____

Company_____

Address_____

GENERAL ELECTRIC LIMITAMP* STARTERS OFFER 30"-DEEP ENCLOSURES WHICH CUT SPACE NEEDS IN HALF

Today you can install General Electric air-break Limitamp starters in half the space normally required by the old-style, 60-inch-deep, high-voltage motor control. In addition to the small compact enclosure (30" deep, 38" wide, 90" high), Limitamp control units are designed for complete front connection, thus eliminating the need for a back aisle. These two features of Limitamp starters assure maximum utilization of available floor space.

Front connection of General Electric Limitamp control also means greater flexibility of arrangement. Units can be mounted back-to-back, back-to-wall, or free standing.

ONLY LIMITAMP CONTROL OFFERS ALL THESE FEATURES

Space savings and flexible arrangement of units are but two of the benefits of G.E.'s Limitamp control. There are many more. For instance:

- Easy installation made possible with roll-out contactor unit and front-connected devices.
- Increased personnel safety provided by three-phase disconnect switch.
- Extra five-square-foot space savings on large motor applications by using higher-capacity fuses to eliminate need for extra fuse cabinet.
- Completely co-ordinated electrical design to give optimum equipment protection.

TAKE ADVANTAGE OF THESE BENEFITS NOW

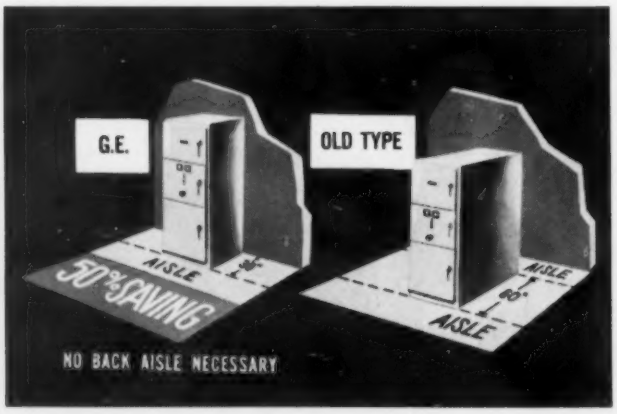
Don't be satisfied with "old-fashioned" high-voltage motor control: specify General Electric's Limitamp control—*leader in design and performance.* Contact your G-E Apparatus Sales Office today, or write Section 783-3, General Electric Company, Schenectady, New York.

Industry Control Department, Roanoke, Virginia

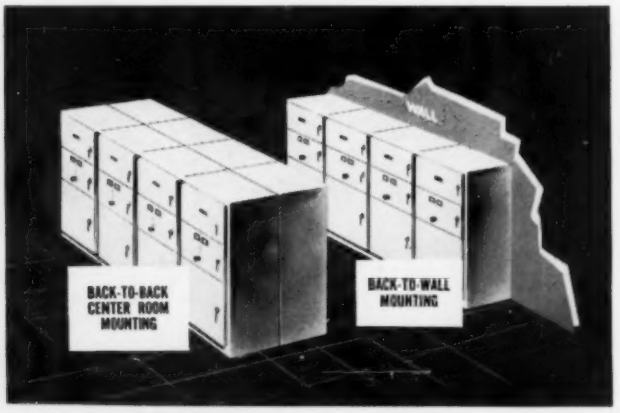
*Reg. Trade-mark of General Electric Company.

Progress Is Our Most Important Product

GENERAL ELECTRIC

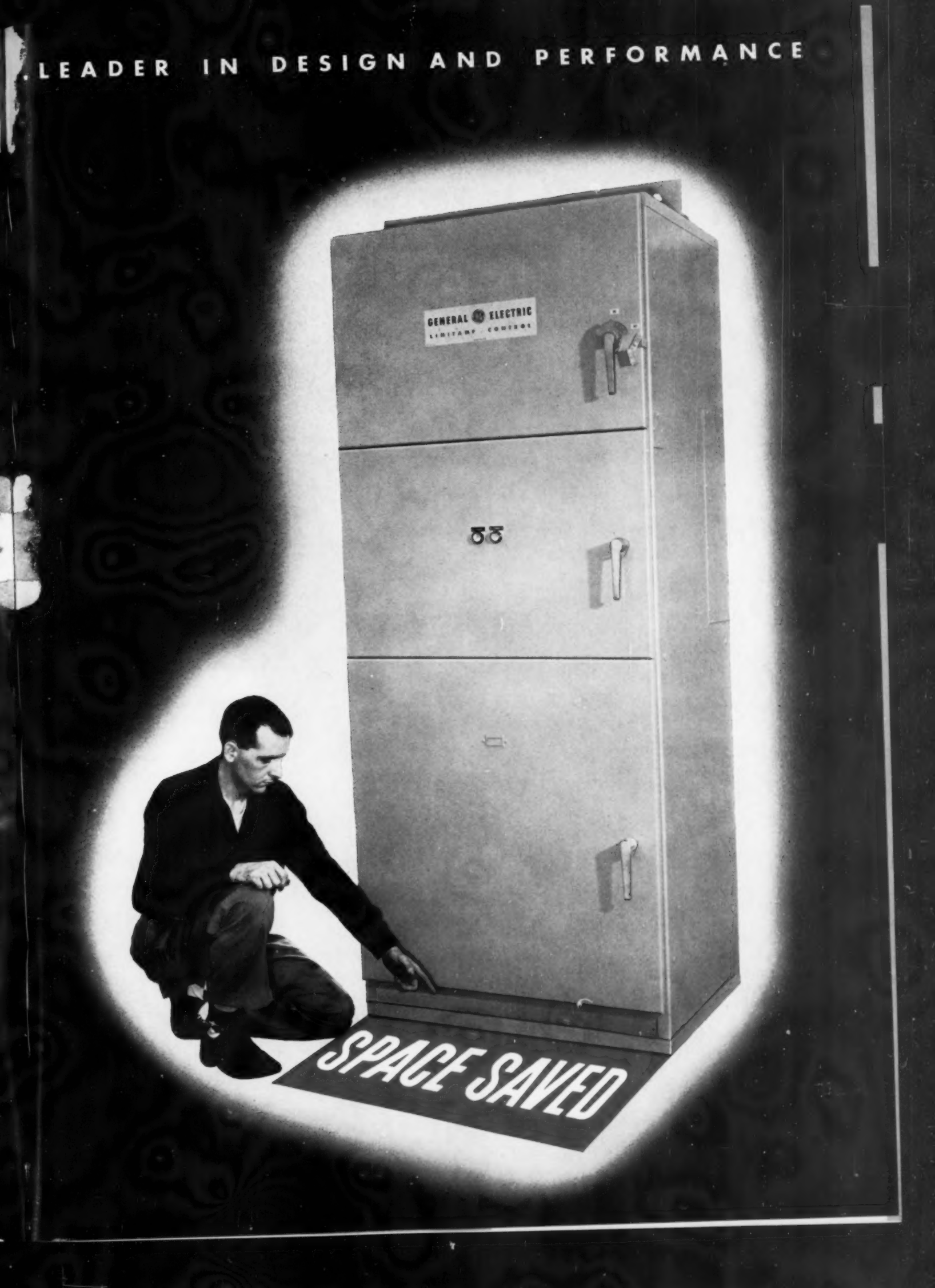


ELIMINATION OF BACK AISLE plus 30-inch-deep Limitamp control units results in floor space savings of 50%.



FLEXIBLE ARRANGEMENT—back-to-back, back-to-wall, or free standing—since units are front connected.

LEADER IN DESIGN AND PERFORMANCE



(*Continued from page 181*)

resumed operations on September 8 has been above expectations and, thus far, we are most satisfied with the tonnage hauled," Mr. Potts said. "However, we still find it necessary to operate most of the ships as long as weather conditions are favorable."

In spite of near-zero temperatures in the Duluth area recently, cargoes of iron ore are moving at a normal rate of speed.

The shipping season for the Pittsburgh Steamship fleet normally ends the first week in December, when the ships begin entering layup ports. This year, the fleet is operating later in the season to make up as much as possible of the ore loss resulting from a 70-day strike of steelworkers and crew officers during the summer.

NEW FURNACE PLANT DEDICATED BY NORTON

▲ Norton Co. dedicated its recently completed electric furnace plant at Huntsville, Ala. on December 10.

The new plant will manufacture a variety of electric furnace materials including boron carbide, fused zirconia, fused magnesium oxide, and fused alumina. These materials are becoming increasingly important to American industry because of their ability to withstand extremely high temperatures and wear. Boron carbide, in addition to being the hardest commercially available man-made material, has several applications in the field of atomic energy.

At a later date, facilities for making aluminum oxide and silicon carbide may be added.

The Huntsville plant is operated by the company's Electro-Chemical Division.

Two other electric furnace plants are located in Chippawa, Ontario, and Cap-de-la-Madeleine, Quebec. Foreign manufacturing plants are located in Canada (two), Ireland, England, Germany, France (two), Italy, South Africa, Australia (two), Argentina, and Brazil.

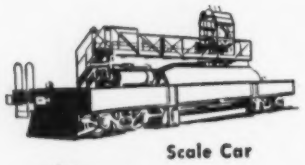
The operations at the Huntsville plant are primarily the electrical fusing of raw materials to make the chemical products, which are then sent to the Worcester plant for further procesing. Some of the products made at Huntsville will be sold directly to other industrial users.

Meetings

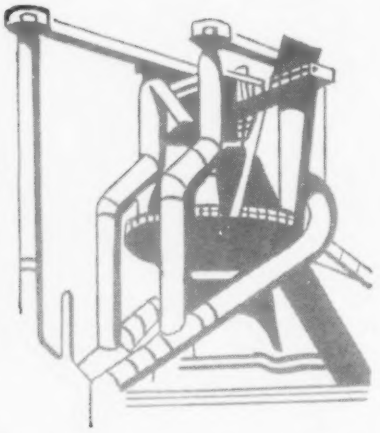
▲ The fifth Welding Show, an industrial exposition sponsored by the American Welding Society, will be held at Convention Hall, Philadelphia, April 9-11, 1957.

During the same week as the show, the socity will conduct its annual National Spring Meeting, April 8-12, at the Hotel Sheraton, Philadelphia, Pa.

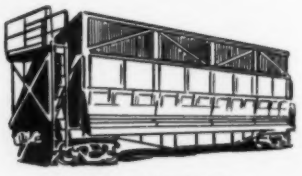
WHEREVER *performance* COUNTS



Scale Car



100-ton Ore Transfer Double Compartment, Bottom Dump



Coke Quenching Car

Atlas Cars are built to resist the high wear factors of continuous service handling abrasive materials. Extra factors of safety in brakes, controls, visibility, and signal devices are incorporated for foolproof service.

Each car is engineered to meet the operating needs of the plant where it will be used.

ATLAS CAR & MFG. CO.
1100 IVANHOE ROAD
CLEVELAND 10, OHIO

Consult Atlas for your Steel Plant Cars

ENGINEERS AND MANUFACTURERS SINCE 1896

buy and use
CHRISTMAS SEALS
fight tuberculosis

TSP cones

"pay off" at

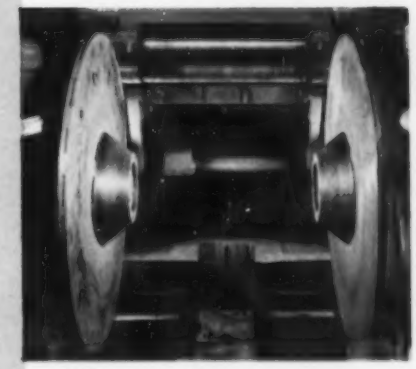
Allegheny Ludlum

Close-up of TSP cone shows no wear.

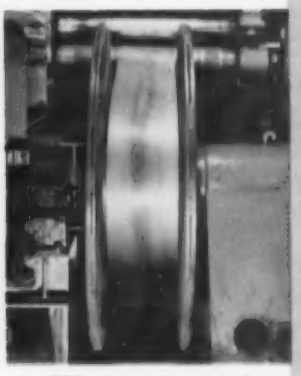
"Tool Steel Process" hardened "pay off" reel cones really pay off in big dollar savings at Allegheny Ludlum Steel Corporation. These TSP pay off reel cones were purchased as replacements for cones which wore out in less than one month of use. The TSP cones show no appreciable amount of wear, after more than *seven months* of constant operation.

Due to the hardness and smoothness of the TSP cones, the last six or eight laps of coil do not become damaged as they did with previous cones when paying off. This results in additional large savings in trimming and scrap.

TSP products do a superior job and last longer because they are hardened by our special process. The file hard surface to the full depth of permissible wear stays smooth and gives maximum life. The core, refined for toughness and ductility, gives maximum strength. TSP products are absolutely guaranteed to give a longer life in the same service than any other product. Write today for information on TSP hardened products for the Steel Industry.



TSP cones show no wear after seven months service.



TSP cones in actual "pay off" operation.

THE TOOL STEEL GEAR AND PINION CO.
CINCINNATI 16, OHIO, U. S. A.

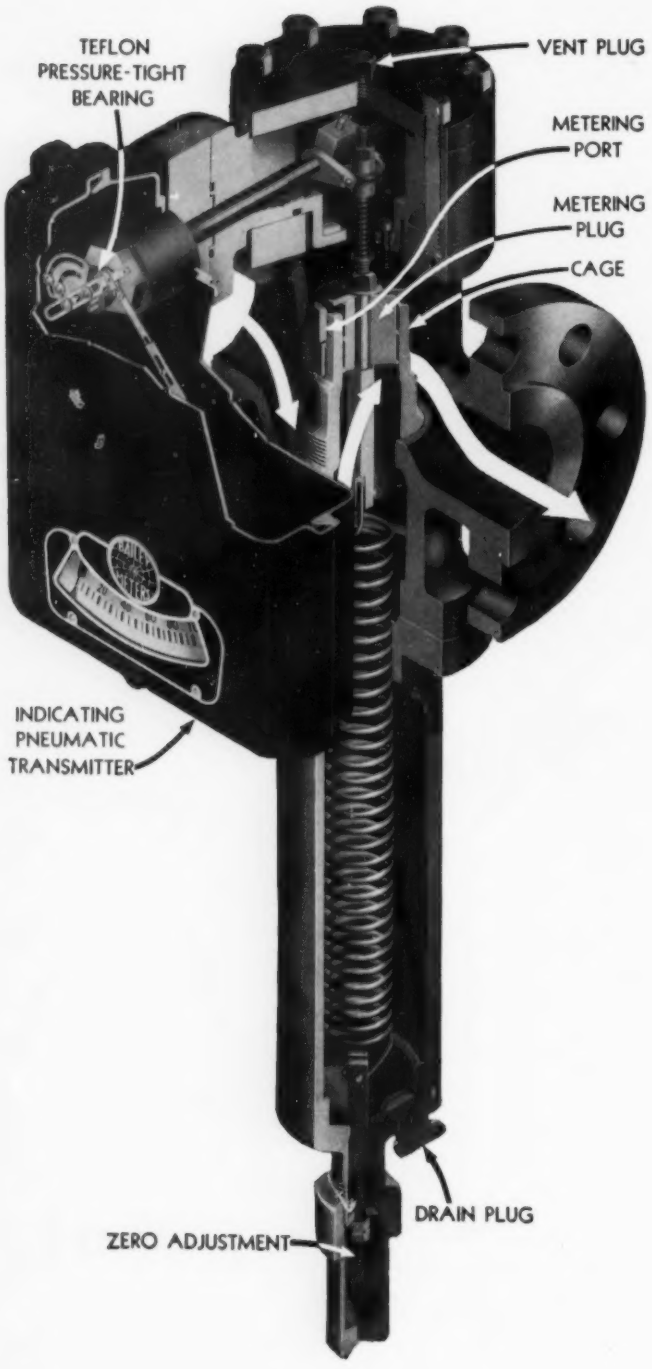
MEMBER OF AGMA

AD 355

Litho in U.S.A.

The World's Standard of Quality Since 1909 for Gears • Pinions • Rolls • Wheels and Other Hardened Products

NOTHING WEARS OUT
in the BAILEY AREA METER
for flow measurement



Simple design and sturdy construction in the Bailey Area Meter mean virtually no maintenance. Grit and dirt in liquid fuels do not harm this meter. Thus, long, trouble-free service under demanding steel mill conditions is assured.

Stainless steel is used for all vital operating parts, so meters can handle corrosive fluids and withstand corrosive atmospheres associated with steel making. Whether you are metering oil, pitch, or tar for open hearth fuel, water for a pickling process or any of a number of other fluids, you can install a Bailey Area Meter in the line and forget it.

The principle of operation is simplicity itself. The metering plug moves directly proportional to rate of flow.

Pneumatic Area Meter Transmitters indicate flow and provide a signal of 3-15 psig or 3-27 psig for indicating, recording, and controlling. Electric Area Meter Transmitters are also available. Both types are useful for fuel totalizing and/or control.

In a typical steel mill application, a Bailey Area Meter is used to measure the flow of Bunker C Oil and pitch to an open hearth furnace. A control system operated by the Area Meter maintains constant flow rates as determined by the operator based on temperature of the molten metal and the roof temperature. After each use of pitch, the meter is steamed out, thus making it available for fuel oil. The thermal and mechanical shock of steaming has no effect on the $\pm 1\frac{1}{2}\%$ accuracy.

The Bailey Area Meter measures flow over a 50 to 1 range. Range spans are 0-550 lb/hr to 0-108,000 lb/hr. The Bailey Recorder used in conjunction with the transmitter may be calibrated in terms of gallons, pounds, or cubic feet per minute. It receives and continuously records one to four pneumatic or electric signals in any combination.

A Bailey Engineer will be glad to call at your plant and explain how you may use this meter. Or, you may wish to write our Iron & Steel Division for Product Specifications P22-4 and E22-4. S-7-1

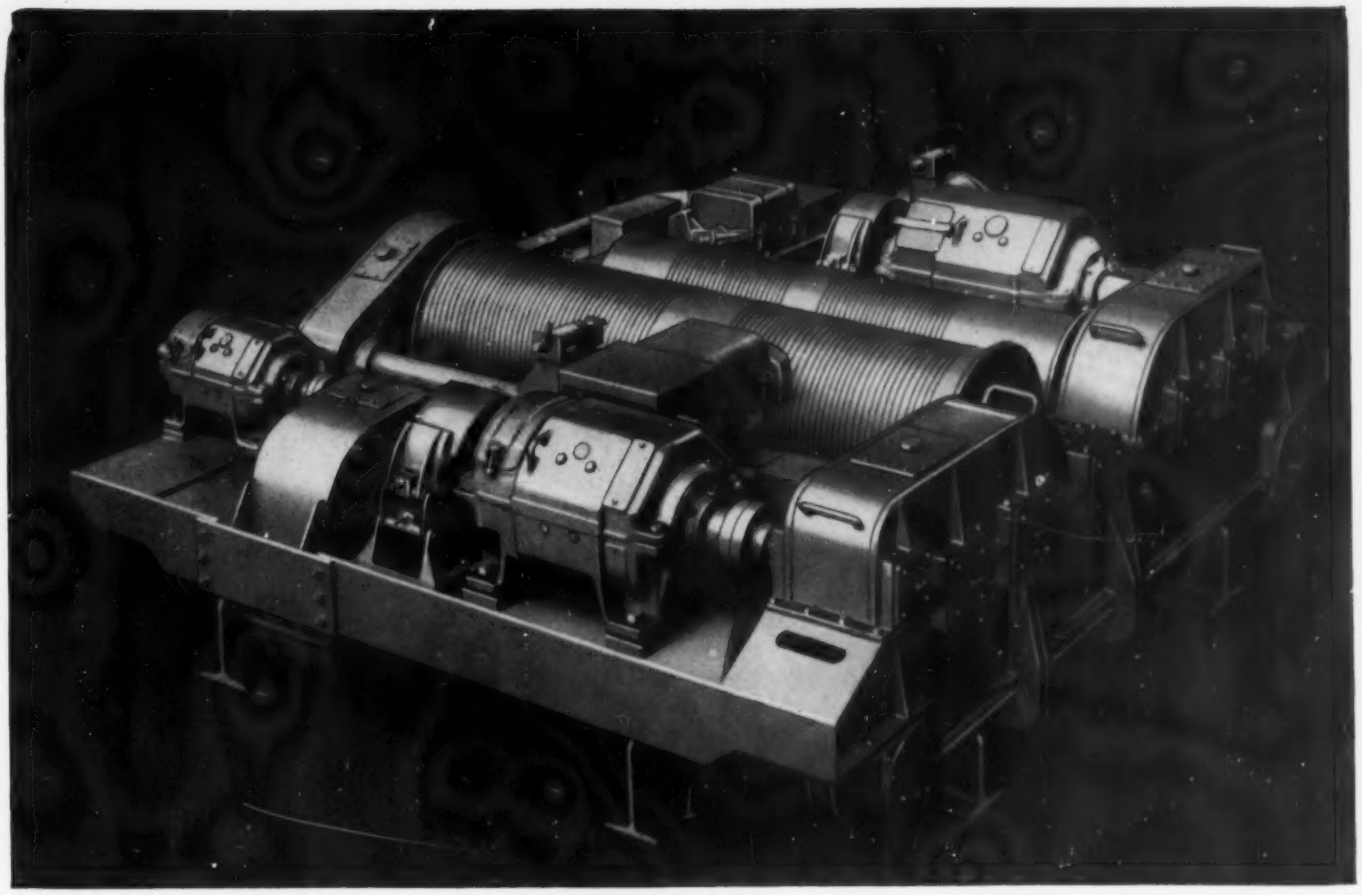
Instruments and controls for power and process

BAILEY METER COMPANY

IRON AND STEEL DIVISION, 1047 IVANHOE ROAD, CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS



VICTOR R. BROWNING

Trolleys

FOR HEAVY DUTY MILL TYPE CRANES

"Simple Design is Sound Design"

We offer a complete line of trolleys built to meet the most exacting requirements. These trolleys are constructed of the finest materials available. No cast iron is used. All shafts are of highest quality alloy steel. All bearings are calculated with a proper life factor for service required as defined by the A.I.S.E. We will build a trolley to fit your special requirements as to gauge, head room, approaches and general arrangement. We also make a complete line of cranes for steel mill use. . . Your inquiries will be welcome.

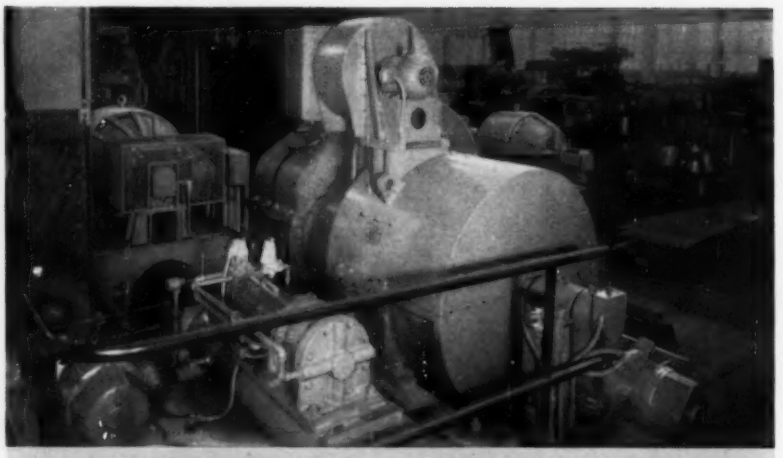
VICTOR R. BROWNING & COMPANY, Inc.

BOX 309, WILLOUGHBY (CLEVELAND), OHIO

Designers and Builders of Electric Overhead Traveling Cranes and Hoists and Electric Revolving Cranes

Modernized brass rolling mill serves as utility unit

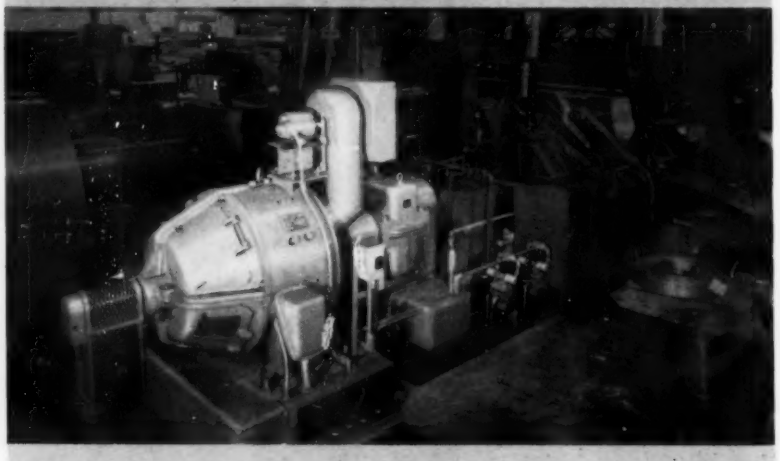
Elliott Motors selected for Key Drives



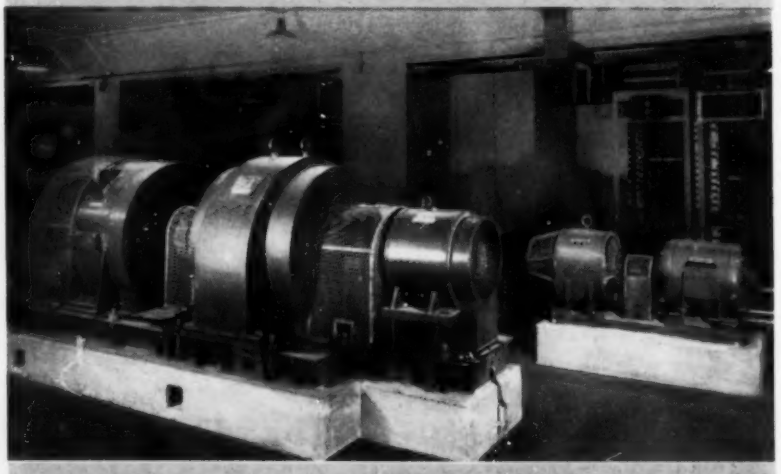
Main drive for the mill consists of an Elliott 500-hp, 575/1280-rpm, 600-volt, d-c motor, with top-mounted ventilating blower driven by an Elliott C-W motor. Uncoiler drive and blocker drive motors are seen at left and right.

Modernization of the brass rolling mill illustrated at the right included converting from a-c to d-c drive. For this, Elliott equipment was selected. After the conversion, this mid-western brass producer was able to run a greater number of alloys, turning this into a utility mill on which rough finishing could be done with much greater flexibility than before. The mill is a 10½-inch and 29-inch by 38¾-inch, four-high cold mill. Elliott furnished the motor drives for the main mill drive, the blocker, and the uncoiler, as well as the main motor-generator and other equipment.

The engineering service offered by Elliott includes complete system layouts for new or revamped installations. You can get full information about this service from the nearest Elliott District Office, or from Elliott Company, Ridgway Division, Ridgway, Pa.



The blocker-drive motor is 75-hp, 575/1280-rpm, 600-volt, also with top-mounted ventilating blower and filter.



The main motor-generator consists of a 500-kw, 600-volt d-c generator and a 15-kw, 250-volt exciter, driven by a 700-hp synchronous motor. At right is the motor-generator for powering auxiliary drives.

ELLIOTT Company

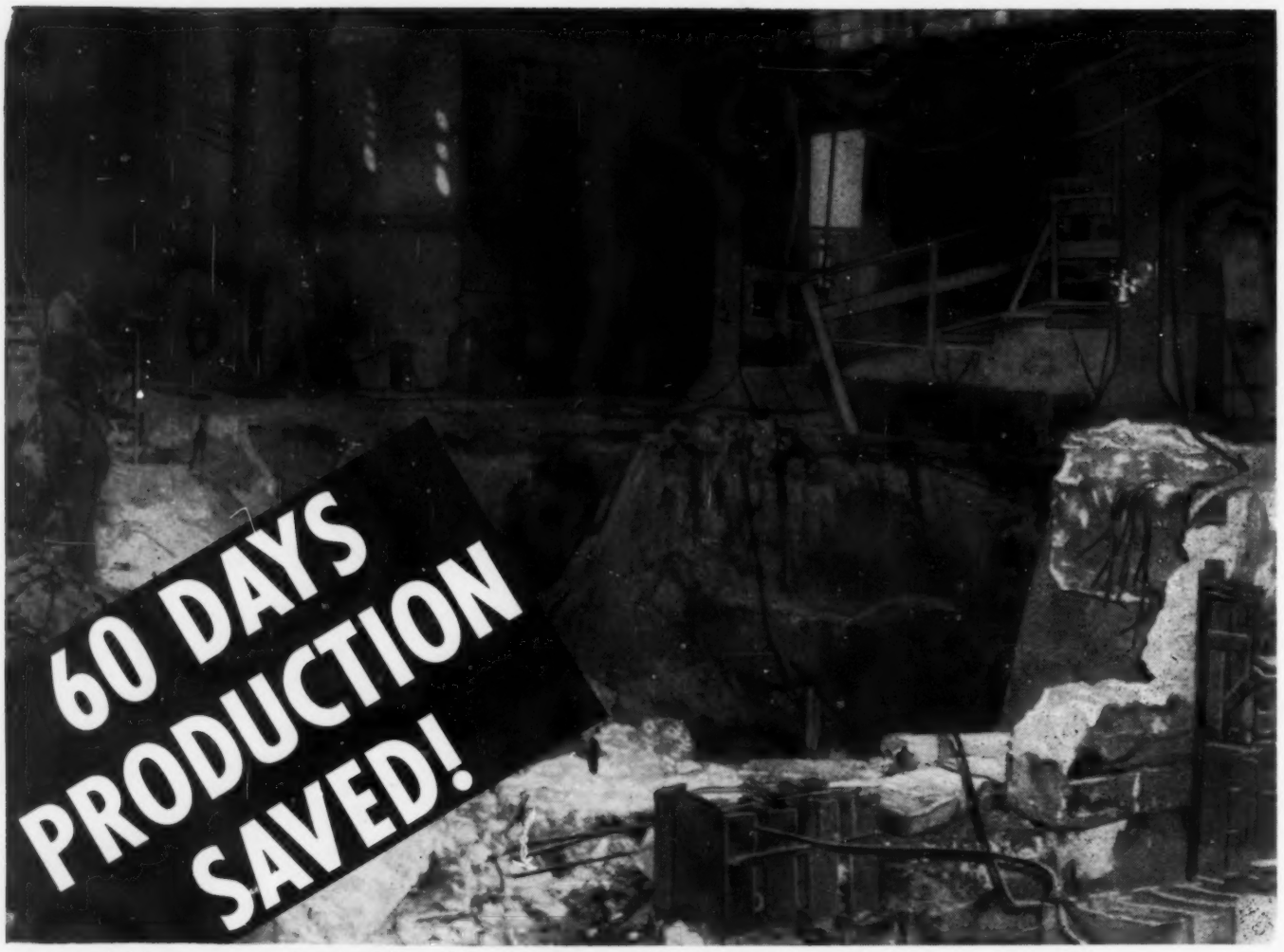
STEAM TURBINES • MOTORS • GENERATORS • DEAERATING HEATERS • EJECTORS • CONDENSERS • CENTRIFUGAL COMPRESSORS • TURBOCHARGERS • TUBE CLEANERS • STRAINERS

R6-27

For Coiling and Sheeting Applications

Stamco has equipment available in a wide range of sizes and speeds for coiling and sheeting applications in mill, warehouse or factory. These bulletins tell the complete story. Request them by number on your letterhead. No obligation.

STAMCO, Inc., New Bremen, Ohio



" . . . and this was accomplished without disrupting other work going on in area . . . and, more important, without an accident!"

Early last year, management of a large steel plant decided that its 90" Blooming Mill had to be replaced. Production requirements demanded that the down-time for making the extensive changes . . . including a complete tear-out of the old foundation . . . had to be held to a minimum.

It was at this point that CHICAGO CONCRETE BREAKING COMPANY was called in for consultation. Realizing the vital importance of every hour to the plant, CHICAGO CONCRETE'S skilled blasting experts used a three-dimensional model of the foundations to lay out the drilling pattern. As a result of this careful planning, 95% of the drilling was accomplished PRIOR TO SHUT-DOWN OF THE MILL AND WITHOUT ANY INTERFERENCE WITH PRODUCTION.

Thus, blasting was performed simultaneously with the removal of the mill. Using modern methods, developed over 35 years of experience, CHICAGO CONCRETE was able to control-blast and remove 5,200 cubic yards of concrete and slag SOME 60 DAYS AHEAD OF THE TIME NORMALLY TAKEN BY OLD-FASHIONED METHODS. Needless to say, reconstruction was able to begin well ahead of schedule.

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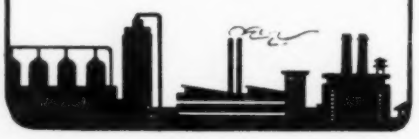

CHICAGO CONCRETE BREAKING CO.

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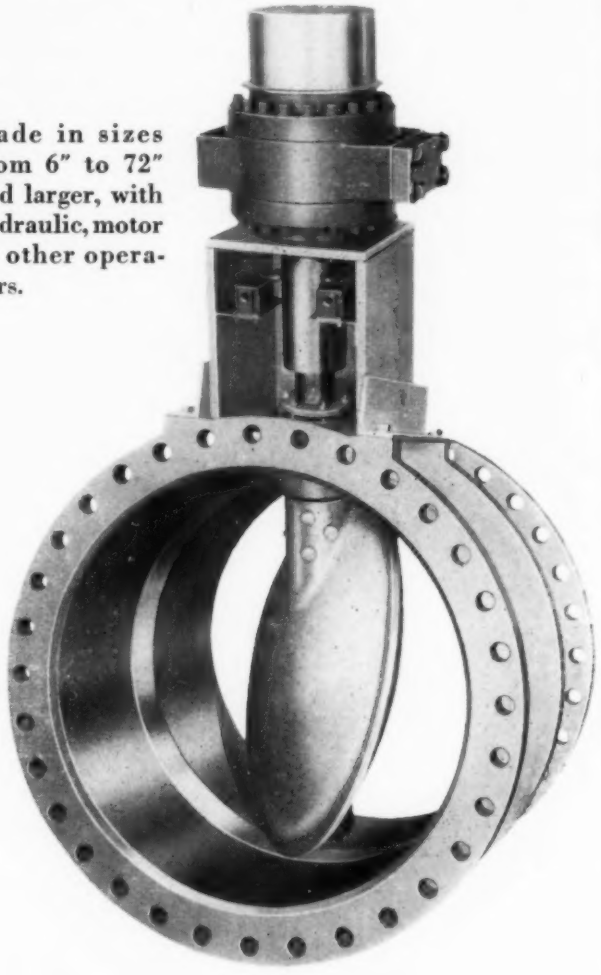

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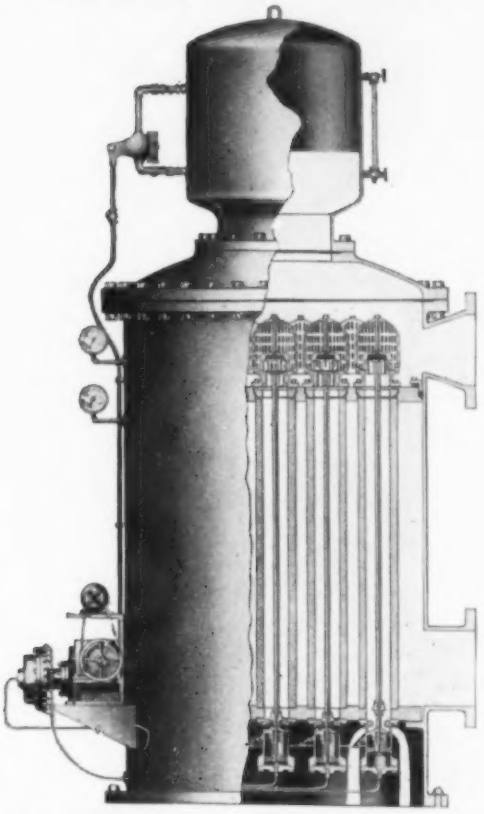

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A constant supply of filtered water is delivered by the Adams AWF filter because it is automatically backwashed . . . tube by tube. Since it is fully automatic, no operator is required.

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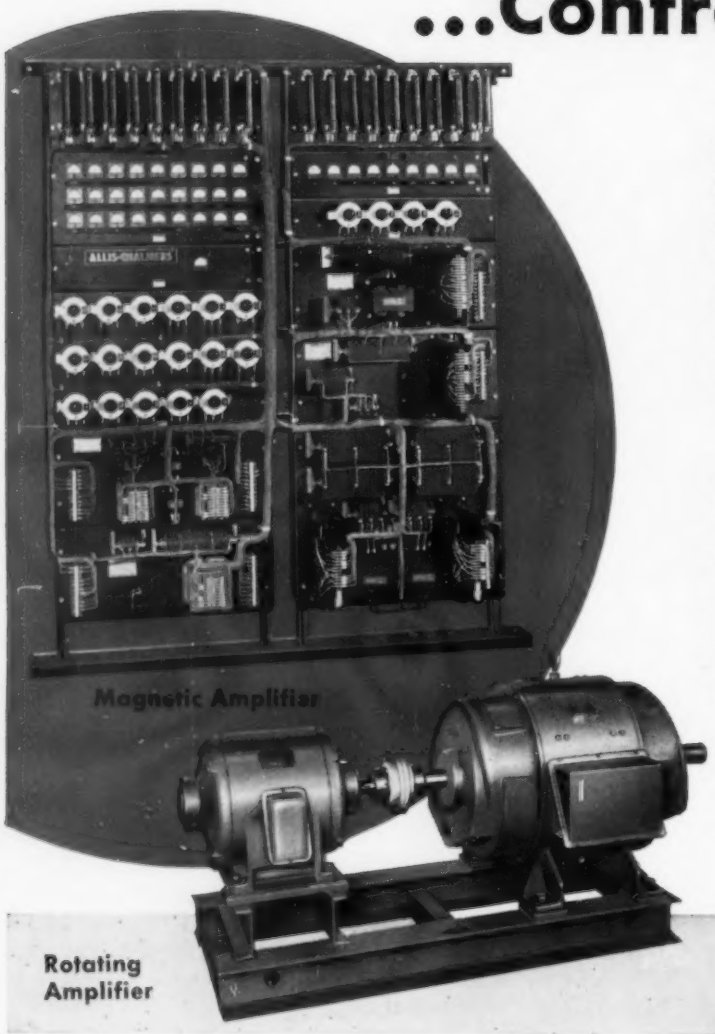

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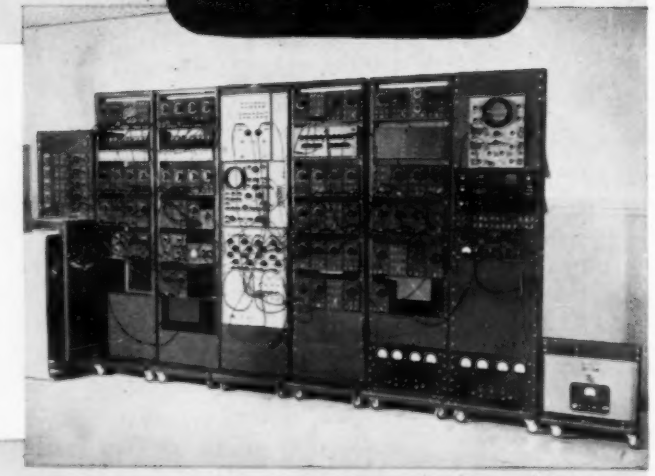
ALLIS-CHALMERS
Regulators



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Personnel News...

J. L. Mauthe has been elected chairman of the board of The Youngstown Sheet and Tube Co. **A. S. Glossbrenner,** former vice president of operations, has been elected president, succeeding Mr. Mauthe. **Walter E. Watson,** former first vice president, has been elected vice chairman of the board. Other elections are **William H. Yeckley,** former manager of steel operations to vice president of operations and **Frederick M. Mayer,** president of Continental Supply Co. (a former Sheet and Tube subsidiary, and now a division) to vice president.

Mr. Mauthe has been president of Youngstown Sheet and Tube since 1950. He joined the company in 1935 as assistant general superintendent of the Youngstown District; became general superintendent in 1937; vice president in charge of operations in 1943; a company director in 1948. From 1913 to 1917 he was assistant superintendent of blast furnaces for National Tube Co. at McKeesport, Pa. He left there to become superintendent of blast furnaces for Midvale Steel Co. In 1919 he went to Gary, Ind., as assistant superintendent of blast furnaces for Illinois Steel Co. From 1921 to 1930 Mr. Mauthe was superintendent of blast furnaces for National Tube Co. at Lorain, Ohio, and from 1930 to 1935 was assistant general superintendent at that plant.

Mr. Glossbrenner has been vice president of operations since 1950 and a director since 1953. He joined Youngstown Sheet and Tube in 1935 as assistant superintendent of the hot strip mill at the Campbell plant and a year later became superintendent of the department. In September, 1942 he was appointed superintendent of the company's Brier Hill Works and 10 months later became general superintendent of the Youngstown district. In 1947 he became assistant vice president in charge of steel operations. He entered the steel industry with the American Sheet and Tin Plate Co. at Gary, Ind., and later went to the South Works of Illinois Steel Co. as foreman of the first wide continuous plate mill in the country. Mr. Glossbrenner was president of the Association of Iron and Steel Engineers in 1950.

Mr. Yeckley has been general manager of steel operations since 1953. He joined Sheet and Tube in 1937 as a test engineer. The following year he was made assistant superintendent of open hearths at Brier Hill and two years later became superintendent of the department. In 1943 he became superintendent of the Brier Hill plant. In 1947 he was named general superintendent of the Campbell steel plant, blast furnaces and Struthers Works and in 1950 became assistant to the vice president in charge of operations.

Charles J. Hunter has been appointed general superintendent of the U. S. Steel Corp.'s South Chicago plant succeeding **A. J. Berdis** who has resigned. **John M. Walsh, Jr.** succeeds Mr. Hunter at Gary Steel Works as assistant general superintendent and **E. Courtney Sorrells** succeeds Mr. Walsh as assistant to the general superintendent. Mr. Hunter started with U. S. Steel at Homestead Works as a metallurgical observer in 1935, working in the metallurgical department in various supervisory capacities until he was transferred to the corporation's Gary Steel Works as chief metallurgist in 1944. In 1948 he became division superintendent of the plant's West Mills. In 1952 he was made assistant general superintendent of Gary, the position he has held until his present appointment. Mr. Walsh started with U. S. Steel at Homestead in 1931. He has held supervisory positions in the blast furnace sections at the corporation's Edgar Thomson Works and Clairton Works, and was transferred to Gary in 1950 as division superintendent of blast furnaces. He was made assistant to the general superintendent in 1954. Mr. Sorrells started his career with U. S. Steel in the Gary coke plant in 1936. After serving in the metallurgical department and holding various positions in the open hearth section, he was made division superintendent of steel production in 1953.

J. Vincent Mahoney has been appointed general superintendent of the Niles branch of the Truscon Steel Division, Republic Steel Corp. Mr. Mahoney, a veteran of 34 years of service with the company, had been a superintendent at Truscon's Youngstown plant for the past eight years.

Russell K. Reichelderfer and **Robert N. Richardson** have been named administrative assistants in the office of operating administration of the Armco Division, Armco Steel Corp., and **William Verity** has been pro-

J. L. MAUTHE

A. S. GLOSSBRENNER

W. H. YECKLEY

C. J. HUNTER

R. K. REICHELDERFER

R. N. RICHARDSON

WILLIAM VERITY

H. P. BLANK, JR.

moted to assistant to the administrative vice president, Armco Division. Mr. Reichelderfer was formerly staff industrial engineer. Prior to his current appointment, Mr. Richardson served as a development engineer under the vice president of operations. Mr. Verity was formerly assistant to the manager, Ashland Works. **George H. Todd** will succeed Mr. Verity as assistant to the manager at Ashland. He was formerly assistant general superintendent. **J. Knox Dye,** superintendent of the Blast Furnace Department at Ashland, has been promoted to assistant to the general superintendent of the Blast Furnace, Foundry, and Transportation and Labor Departments. **James L. Brady,** assistant superintendent of the Blast Furnace Department, succeeds Mr. Dye as Blast Furnace Department superintendent. **Myron D. Bailey,** general foreman of the Foundry Department, becomes superintendent of the Foundry Department.

H. Phillip Blank, Jr., has been appointed assistant industrial engineer of the Cleveland plant of the Steel and Tubes Division of Republic Steel Corp. Mr. Blank joined Republic in 1949 and in 1952 was appointed a senior time study engineer, the position he held at the time of his current appointment.

Dennis J. Carney was named division superintendent, Steel Producing, Duquesne Works, United States Steel Corp. He was formerly superintendent, No. 2 Open Hearth at South Works, Chicago, Ill. He has served with U. S. Steel since 1942.

Emerson R. Miller has been appointed to the post of assistant to the general superintendent, and **William D. Millar** to the position of division superintendent, Coke and Coal Chemical Works and Blast Furnaces, Central Operations, Fairless Works. At the same time **R. E. Madden** was advanced to superintendent, Maintenance, Rolling Division, to succeed **J. E. Foldessy,** who has been appointed assistant works chief engineer of U. S. Steel's Gary Works, Gary, Ind. **J. F. O'Hear** was advanced to assistant superintendent, Maintenance, Rolling Division, and **Loren Belcher** to general formean, Maintenance, Billet and Bar Mills. Mr. Miller started with U. S. Steel in 1924 at the Carnegie-Illinois Steel, Mingo Works, Mingo Junction, Ohio, as assistant superintendent of blast furnaces. In 1939, he was transferred to the Homestead Works as assistant superintendent of the Carrie Furnaces. Seven years later he was appointed superintendent of blast furnaces at the Duquesne Works, a position he held until being transferred to the Fairless Works in 1951. Mr. Millar began his career with U. S. Steel as a blast furnace apprentice at the South Works in 1936. He was advanced to assistant to divisional superintendent Furnace Practices in 1941 and from then on advanced through the various stages in the blast furnace department at South Works until 1950 when he was appointed division superintendent, Blast Furnaces, the position he has held up to the present advancement to the Fairless Works.

Harold W. Dawson has been promoted to division industrial engineer of Republic Steel Corp.'s Truscon

H. W. DAWSON

Steel Division in Youngstown, Ohio. Mr. Dawson, prior to his promotion, had been serving as assistant division industrial engineer.

James P. Haight was appointed vice president in charge of engineering and purchasing for Aluminum Co. of America, succeeding **Thomas D. Jolly** who has retired after a career of nearly 42 years with the company. Mr. Haight joined Alcoa in 1920. He worked in various divisions of Alcoa's Edgewater, N. J., opera-

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10' Betts Vertical Boring Mill
12' Cincinnati Vertical Boring Mill
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GAS PLANT EQUIPMENT
AND INDUSTRIAL FURNACES

tions until 1929, when he was assigned to the company's central engineering division. In 1931 he became chief engineer of fabricating operations at Alcoa, Tenn., and, in 1937, returned to Edgewater as chief works engineer. During World War II Mr. Haight supervised construction of the government-owned Trentwood Works at Spokane, Wash., becoming works manager on its completion. In 1946 he returned to Alcoa as works manager of the fabricating division. A year later he was transferred to Pittsburgh as assistant fabricating division manager, and, in 1951, was named manager. He was appointed chief engineer for Alcoa in 1954. Last April he was elected a vice president. Mr. Jolly joined Alcoa in 1915 and served in many operating and purchasing capacities until he was made chief engineer and director of purchasing in 1937. In this capacity he handled Alcoa's $300 million expansion program prior to World War II. In 1942 he was named vice president in charge of engineering and purchasing. Besides directing Alcoa's own wartime expansion program, he had the job of building $450 million of government-owned plants constructed and operated by Alcoa during the war. Later, he was responsible for Alcoa's continuing multi-million dollar postwar expansion program.

Sidney L. Eastman, formerly chief engineer of The Cleveland Worm & Gear Co., has been appointed vice president in charge of Engineering. Mr. Eastman has been associated with the firm in various engineering and sales capacities since 1927. **John R. Dingle,** formerly process engineer for Cleveland Worm & Gear and its affiliate, The Farval Corp., has been appointed vice president in charge of manufacturing for both firms. Mr. Dingle has been associated with the two companies since 1946. **Lee O. Witzenburg,** formerly general sales manager of Cleveland Worm & Gear and Farval, has been appointed vice president in charge of sales for both firms. Mr. Witzenburg has been associated with the two companies since 1950.

J. Clinton Weight has been employed by the Waverly Oil Works Co. of Pittsburgh, Pa. as a special representative to help reintroduce the Waverly line to the steel industry. Prior to this new assignment, Mr. Weight had been employed by the Esso Standard Oil Co., New York as national accounts representative for the steel industry. He also worked previously to this for four years for the Bethlehem Steel Co. as a lubrication foreman, and was employed before that for eight years by the Farval Corp. as an installation supervisor. He is a member of the AISE and the ASLE.

O. V. Tally, director of industrial sales of Allis-Chalmers Manufacturing Co.'s Industries Group since 1954, has been appointed manager of the firm's Washington district. Mr. Tally joined Allis-Chalmers in 1926 and served as a representative successively in the New York, Washington and Philadelphia districts. In 1943 he was named manager of the St. Louis district. In 1950 he became manager of the Midwest region with headquarters in Chicago and in 1954 director of industrial sales of the Industries Group. **R. N. Landreth,** who has been manager of the Washington district since 1950, has been assigned to the Industries Group sales staff.

Stanley B. White, manager of aluminum plant operations for Kaiser Aluminum & Chemical Corp. has been elected a vice president of the corporation. Mr. White joined Kaiser in 1947 as rolling mill superintendent at the Trentwood, Wash., Works. Two years later he was named production superintendent and in 1950 was promoted to plant manager. In August, 1950, Mr. White was transferred to the company's headquarters in Oakland as manager of fabricating plant operations, and in 1953 was appointed manager of aluminum plant operations.

Kenneth M. Wilhelms has been named superintendent of the Laclede Works, Laclede-Christy Co. Division, H. K. Porter Co., Inc. He joined Laclede's Quality Control Department in 1946, and two years later was made factory foreman, later to become assistant works superintendent in 1952, until his recent promotion.

A. B. Vestal has been named planning engineer—Plant Development Division for Jones & Laughlin Steel Corp. He was employed by J&L as a steam efficiency engineer from 1937 to 1940 before he joined U. S. Steel in July, 1940. He held various engineering positions at U. S. Steel, lastly as assistant chief, Rates and Incentives, from 1948 to 1950. He also was employed by

S. L. EASTMAN

J. R. DINGLE

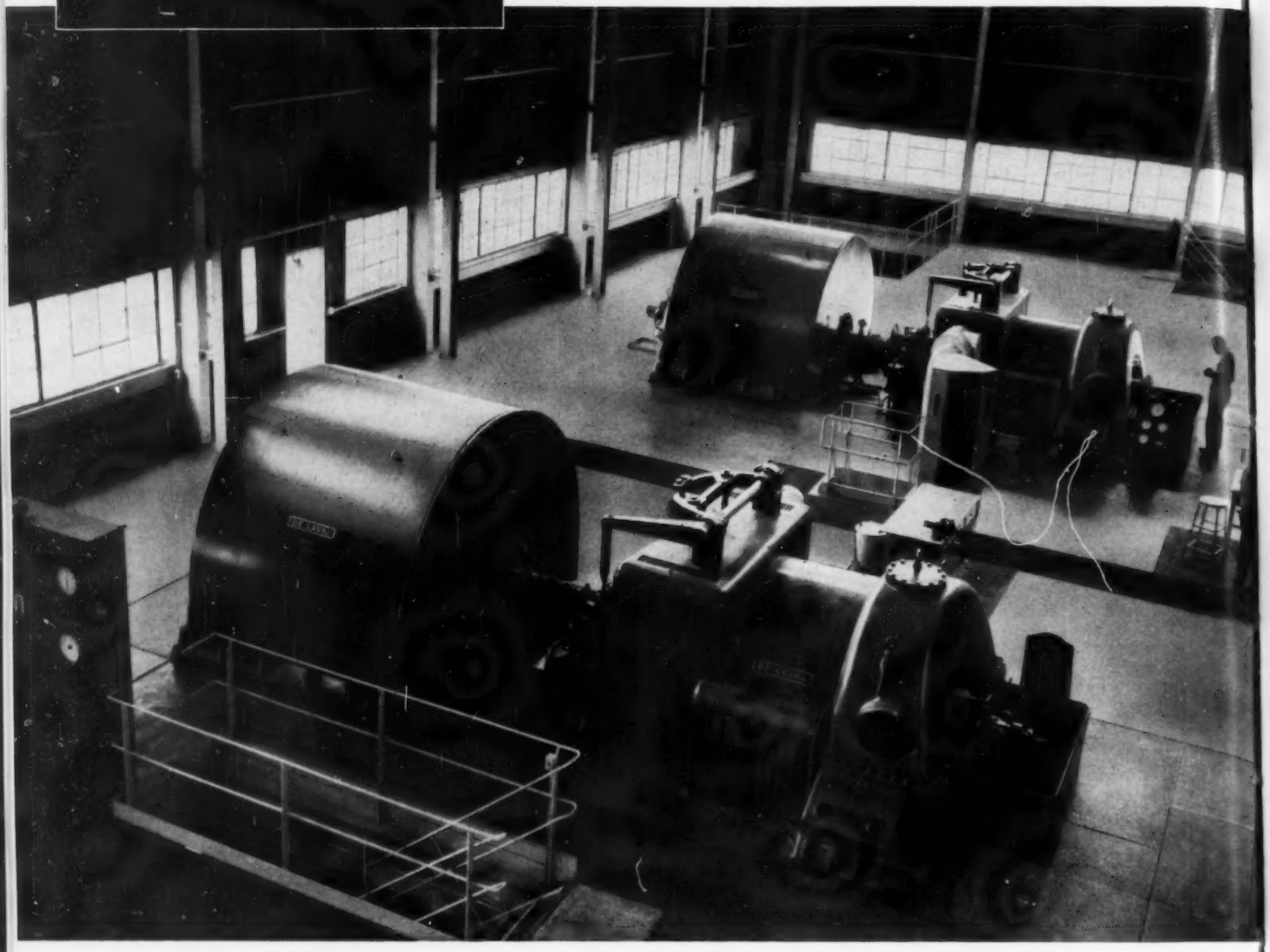
L. O. WITZENBURG

J. C. WEIGHT

DE LAVAL

BLAST FURNACE BLOWERS

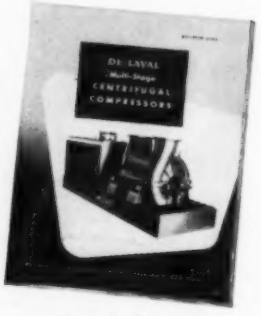
deliver 110,000 cfm each for McLouth Steel



These two De Laval turbine-driven centrifugal blowers do a round-the-clock job in the McLouth Steel plant, Trenton, Michigan. Each has a rated capacity of 110,000 cfm of air; discharge pressure is 30 psig. Each is driven by a 12,400 hp, 2950 rpm De Laval steam turbine operating under steam conditions of 600 psig, 825 F with 2″ hg.

De Laval compressors are designed individually for each application to assure maximum efficiency and range of operation. Construction is rugged throughout. Casings and perfectly balanced rotors are built to take punishment. All parts are precision-made to limit gages. Materials are selected which will best meet the particular conditions of corrosion, pressure and temperature.

De Laval centrifugal blowers are built in single and multi-stage types to supply air in volumes up to 150,000 cfm for all classes of service in steel, gas and coke plants. The wealth of application experience acquired by De Laval over the years assures a correct and economical solution to your blower problem.



Send for Bulletin 0504

DE LAVAL *Centrifugal Blowers*

DE LAVAL STEAM TURBINE COMPANY

870 Nottingham Way, Trenton 2, New Jersey

360

Firth Sterling Steel and Carbide, Pittsburgh, and Edwards and Barnes, Pittsburgh, Pa. He rejoined J&L as supervisor, Planning and Operations Analysis in January, 1954.

Lothar S. Heym has been appointed Youngstown district engineer for the Mannesmann-Meer Engineering and Construction Co., Inc. Mr. Heym assumes

L. S. HEYM

charge of the company's newly opened district office in Youngstown, Ohio. Before joining Mannesmann-Meer six months ago, he was in private mechanical engineering practice, doing machine design work for several mill machinery builders.

Regis O. Bridge has been appointed director of purchases for the Crucible Steel Co. of America. Mr. Bridge, who has served as the company's purchasing agent since 1950, began his business career at Crucible's Midland Works in 1919. He transferred to Park Works, Pittsburgh, in 1925 where he became supervisor of supplies and stores. Mr. Bridge was named the company's assistant purchasing agent in 1945.

John G. McDonnell has been appointed sales engineer of Research-Cottrell, Inc.'s Pittsburgh district office. He was formerly with the Weirton Steel Division of National Steel Corp. and, more recently, sales engineer with S. P. Kinney Engineers, Inc.

George A. Most, Jr., has been appointed Boston district manager of Link-Belt Co. For the past four years Mr. Most has been district manager of the Moline, Ill., office. Other changes in the company's district office sales organization include: **J. Charles Bullock**, appointed Moline, Ill., district manager, succeeding Mr. Most; **Gene A. Zwerner,** appointed Albany, N. Y., district manager, succeeding Mr. Bullock; **C. C. Wiley,** appointed Washington, D. C., district manager succeeding Mr. Zwerner; **Paul Waldorf**, appointed Baltimore, Md., district manager, succeeding Mr. Wiley.

S. S. "Bert" Inch, formerly vice president of Kaiser Aluminum & Chemical Sales, Inc., has been named vice president and director of sales of the Kaiser Aluminum & Chemical Corp. **John E. Menz**, formerly general sales manager of Kaiser Aluminum & Chemical Sales, Inc., has been named vice president and general sales manager, succeeding Mr. Inch.

Edward C. Delano has been named assistant to the vice president, Westinghouse Electric Corp., effective January 1. Mr. Delano will serve on executive assignment for special situations in the Boston, Mass., district. **Paul B. Shiring,** electric utility manager of the northeastern region, has been named assistant manager of the Boston district, and will become manager on January 1, succeeding Mr. Delano. Also announced are the appointments of **Frederick R. Malone** as regional electric utility sales manager and **William G. Cheney** as area sales manager of the New York City district.

Hugh F. Beeghly has been appointed to the new position of research associate for Jones & Laughlin Steel Corp. Mr. Beeghly, who formerly was section head, Chemistry, in J&L's Research and Development Department, in his new position assumes the responsibility for applying developments in the nuclear energy field to the processes of the steel corporation, and for recommending application of present J&L products or development of new products for nuclear purposes. He also will act as consultant on new analytical techniques and on research programs. Two other promotions were also announced: **Earle F. Young, Jr.,** senior development engineer for J&L. He formerly was a process engineer—Chemical Engineering Services; **Donald J. Shellenberger,** senior process engineer. He formerly served as process engineer — Chemical Engineering Services.

Kenneth H. Beer has been named executive vice president of the Resolite Corp. He has been with Reso-

K. H. BEER

lite for five years. Prior to 1951, he was associated with the Corrulux Corp., General Shoe Corp., and Ford Motor Co. in executive sales capacities.

W. A. Patterson has been named chief engineer of Steel Processing Co., a subsidiary of Fort Pitt Bridge Works. He has been associated with the engineering departments of these two companies since 1927.

Charles F. O'Riordan has been appointed manager of the Midwest region of Allis-Chalmers Manufactur-

ing Co.'s Industries Group with headquarters in St. Louis, Mo. He succeeds **J. F. Burrus,** recently named an assistant general manager in the firm's Power Equipment Division. **Joseph M. Duncan,** a sales representative in the New Orleans, La., district since 1951, succeeds Mr. O'Riordan as manager at Atlanta, Ga.

J. L. Tunstead, sales manager, Metal Products Division of Koppers Co., Inc. since 1949, has been appointed a vice president of the company. At the same time he was named as director of sales and assistant manager of the Marketing Department. In his new position he will have his headquarters in Pittsburgh. Succeeding Mr. Tunstead at Baltimore is **Harry P. Neher, Jr.,** who has been assistant sales manager of the company's Tar Products Division. Both men will assume their new duties about January 1.

Leonard J. Edwards has been appointed manager of the Furnace and Oven Division of W. S. Rockwell Co. Mr. Edwards was previously vice president of C. I. Hayes, Inc., and sales engineer for General Alloys Co.

Harry C. Burton has been appointed administrative assistant to the vice president—Industrial Relations, Pittsburgh Steel Co. A veteran of 22 years in the steel industry, Mr. Burton came to Pittsburgh Steel from Great Lakes Steel Corp., where he had been serving as coordinator, division of Industrial Relations.

Kenneth W. Donle has been appointed manager of Product Engineering for the Tube Reducing Corp. Mr. Donle has been with Tube Reducing since 1951 during which time he has been chief metallurgist, and more recently manager of the Rockdrawn Tubing Division. Prior to that Mr. Donle was associated with the National Tube Division, U. S. Steel Corp., where he held the post of assistant chief metallurgist for the Gary, Ind. plant.

Thomas J. Carbine has been appointed Philadelphia district sales manager for Laclede-Christy Co. Division, H. K. Porter Co., Inc. His sales district includes eastern Pa., parts of N. J., and W. Va., Md., Del., Va., and the District of Columbia. Sales representatives in this newly established sales district are **Norman W. Harris** and **Kenneth R. Bartholomew.**

Samuel C. Clarke was named manager of sales, Chambersburg Engineering Co. Mr. Clarke has been connected with the sales and advertising departments of the company for the past eight years.

E. E. McKeen has been named to a newly created position of general erecting manager for United States Steel's American Bridge Division, with headquarters in Pittsburgh. Also announced was the appointment of **George W. Faulkner** to succeed Mr. McKeen as erecting manager for the 11 western states, with headquarters at San Francisco.

Enoch While, chief inspector at Allis-Chalmers Manufacturing Co.'s Norwood, Ohio, Works since 1947, has been named works manager there succeeding **J. F. Costigan,** recently appointed assistant director of manufacturing, Industries Group. Mr. While joined Allis-Chalmers in 1945 as assistant chief inspector. **R. C. Lathrop,** assistant chief inspector since 1947, succeeds Mr. While as chief inspector, and **C. E. Wikoff,** general foreman inspection since 1953, becomes assistant chief inspector at Norwood Works.

Obituaries

Louis H. Derrer, 62, vice president and general manager, steel works, Algoma Steel Corp. Ltd., died November 25.

Charles C. Myers, 49, superintendent of rolling mills, U. S. Steel Corp.'s Duquesne Works, died recently.

James Kniveton, vice president—engineering, Selas Corp. of America, died November 12. Associated with Selas since 1935, when he joined the company as an engineer, Mr. Kniveton was responsible for many heat processing developments in the metal, ceramic, glass and other industries, and a number of patents have been issued in his name.

Philip B. Mansfield, electrical engineer, Republic Steel Corp., Buffalo, N. Y., died recently. Also, **Harold H. Warnock,** superintendent of strip and bar mills, Republic Steel Corp., Youngstown, Ohio, died in November.

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in PITTSBURGH and HAMMOND
For greater safety and economy, have your Alloy Sling Chains returned to either our Pittsburgh or Hammond plant for repair, inspection and testing, at nominal cost.
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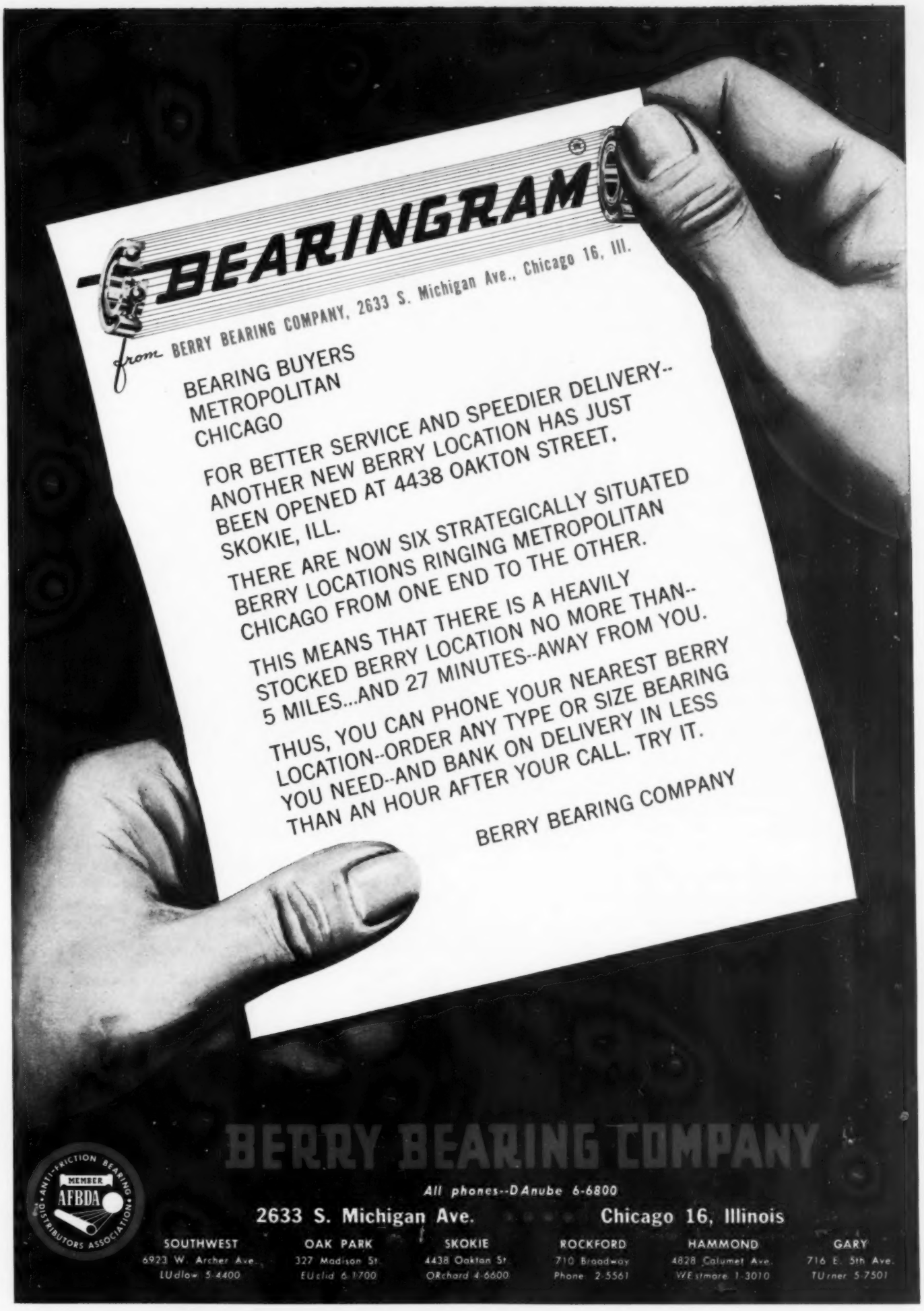
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from BERRY BEARING COMPANY, 2633 S. Michigan Ave., Chicago 16, Ill.
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FOR BETTER SERVICE AND SPEEDIER DELIVERY--
ANOTHER NEW BERRY LOCATION HAS JUST
BEEN OPENED AT 4438 OAKTON STREET.
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THERE ARE NOW SIX STRATEGICALLY SITUATED
BERRY LOCATIONS RINGING METROPOLITAN
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THIS MEANS THAT THERE IS A HEAVILY
STOCKED BERRY LOCATION NO MORE THAN--
5 MILES...AND 27 MINUTES--AWAY FROM YOU.
THUS, YOU CAN PHONE YOUR NEAREST BERRY
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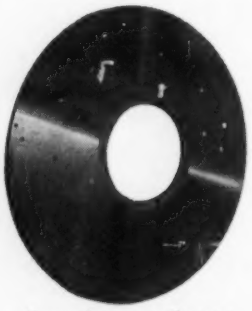
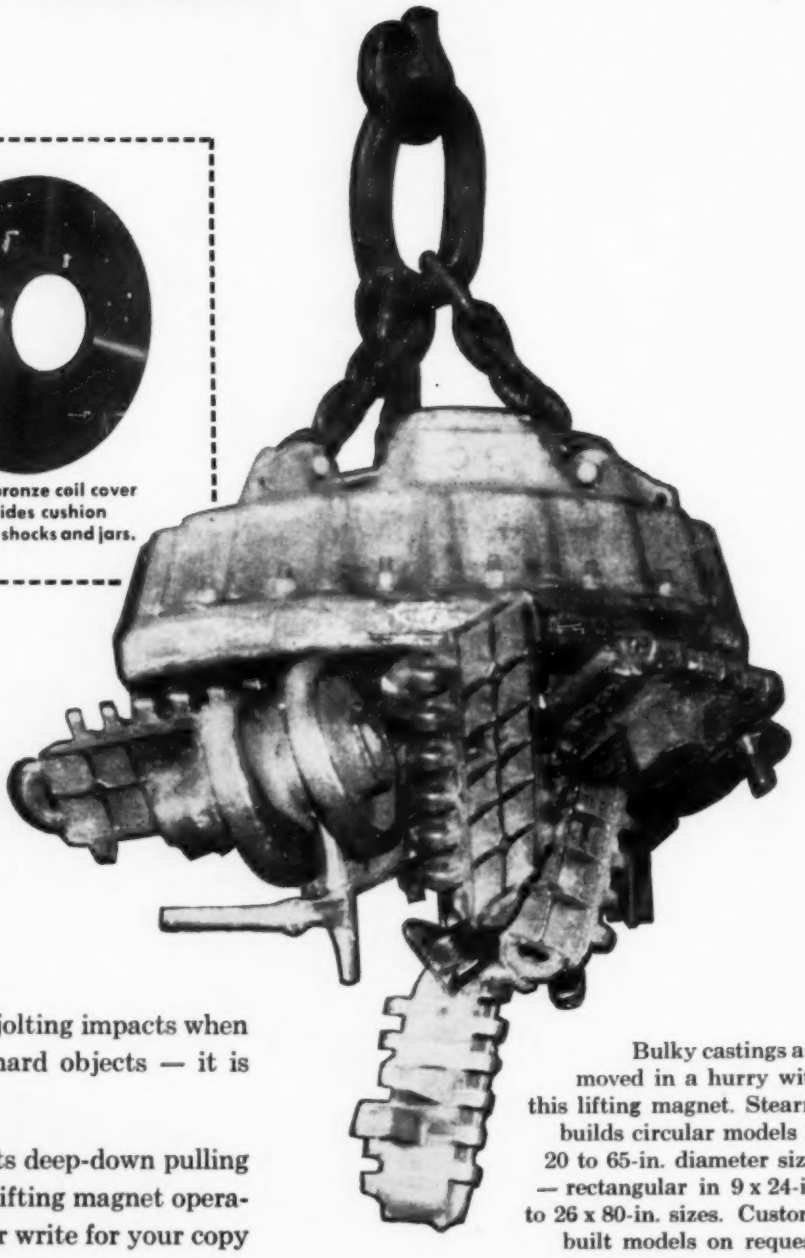
Exclusive Built-in Shock Absorber

PROTECTS DEEP-DOWN PULLING POWER



Heavy bronze coil cover provides cushion against shocks and jars.



Bulky castings are moved in a hurry with this lifting magnet. Stearns builds circular models in 20 to 65-in. diameter sizes — rectangular in 9 x 24-in. to 26 x 80-in. sizes. Custom-built models on request.

Powerful, deep-field Stearns lifting magnets are built with an extra wall of protection against shocks and jars. In addition to the regular coil shield of chrome-nickel steel, Stearns adds a heavy bronze coil cover — an *exclusive* feature.

This shock-absorbing cover provides a double advantage—it is both ductile and tough. It not only absorbs jolting impacts when the magnet is banged against sharp, hard objects — it is strongly resistant to damage.

Find out *all* the ways Stearns protects deep-down pulling power — gives you long life, profitable lifting magnet operation. See your Stearns representative or write for your copy of Bulletin 35-C.

1078

STEARNS MAGNETIC PRODUCTS

A DIVISION OF THE INDIANA STEEL PRODUCTS COMPANY • VALPARAISO INDIANA

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DECEMBER, 1956

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(1) Rolling Mills and Mill Auxiliary Equipment

The Waterbury Farrel Foundry & Machine Co. is offering a new 36-page book cataloging its complete line of rolling mills and rolling mill auxiliary equipment for ferrous and non-ferrous metal. Covering over 25 different types of machinery, the catalog has its contents conveniently grouped into three sections. The three sections cover; (1) Main equipment: strip mills, rod mills, special mills, gang slitters and chain draw benches; (2) Auxiliary equipment for strip, rod, wire and tube mills; and (3) Reference tables including strip coil weight and length calculating graphs and tandem rod mill rolling schedules. (Catalog R)

(2) Industrial control Systems

Westinghouse Electric Corp., has available a new booklet discussing static industrial control systems. The booklet describes Cypak systems, what they do, where they are being used and how to apply them. Also included are application stories on the broad range of machinery that Cypak can control in industry. A new line of contactless limit switches and contactless pushbuttons are covered. (B-6738)

(3) Stitcher and Shear

The Herr Equipment Corp., has available a new bulletin describing their automatic stitcher and shear. The advantages of this new equipment are discussed, and illustrations showing the stitcher, the stitch and the twin cut shear are included. (Bulletin No. 563)

(4) Magnetic Particle Inspection

Magnaflux Corp., has released a new booklet describing the workings of magnaflux-magnaglo. The 16-page booklet explains the how, why and where of a proven way to control quality, increase useful production, improve maintenance, and raise profits. Also included is a discussion on the causes of cracks, and the uses of magnaflux-magnaglo in manufacturing.

(5) Static Control Elements

An eight-page bulletin explaining static control is now available from General Electric Co. The bulletin lists the advantages and describes the components of this static control system. How static control operates without moving parts is explained as well as the logic function concept, and logic functions and conventional control. Also covered are the basic principles of static control, circuit characteristics, and monitor lights and amplifiers. (GEA-6578)

(6) Unit and Blast Heaters

A catalog describing cast iron steam heat transfer surface unit heaters (both horizontal and down blow), blast heaters and radiators has been published by D. J. Murray Manufacturing Co. The catalog describes and illustrates the one-piece construction high-test cast iron heating sections together with air distribution charts, heating capacities, conversion tables, etc. In addition the catalog discusses the treatment of corrosion in unit heaters. (Catalog GP No. 956)

(7) Fluid System Specialties

Available from Parker Appliance Co., is a catalog describing their fluid system specialties. Such specialties as clips for support of tube lines, dual heat transfer coil, pressure snubber for protection of gages, and manifold valve are illustrated and discussed. (Catalog 4395)

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81	TAYLOR INSTRUMENT COMPANIES	BULLETIN 98274	Flow transmitter
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and only USG® brushes have STATITE® permanent shunt connections

If you are having trouble with shunts jarring loose or being pulled out, we suggest you try USG Brushes with Statite. Statite is a permanent shunt connection needing no hammerclips. It can't be jarred out even under severe operating conditions, and will assure your electric motors of steady maintenance-free performance. Statite eliminates the need for riveted shunt connections. In addition, Statite shunt connections retain their original low millivolt shunt drop, cannot oxidize, and are unaffected by temperature extremes. USG Brushes are manufactured in a variety of types and sizes for all applications from fractional horsepower to diesel generator. Grades available include carbon and carbon-graphite, electrographitic, graphite, metal graphite, and silver graphite.

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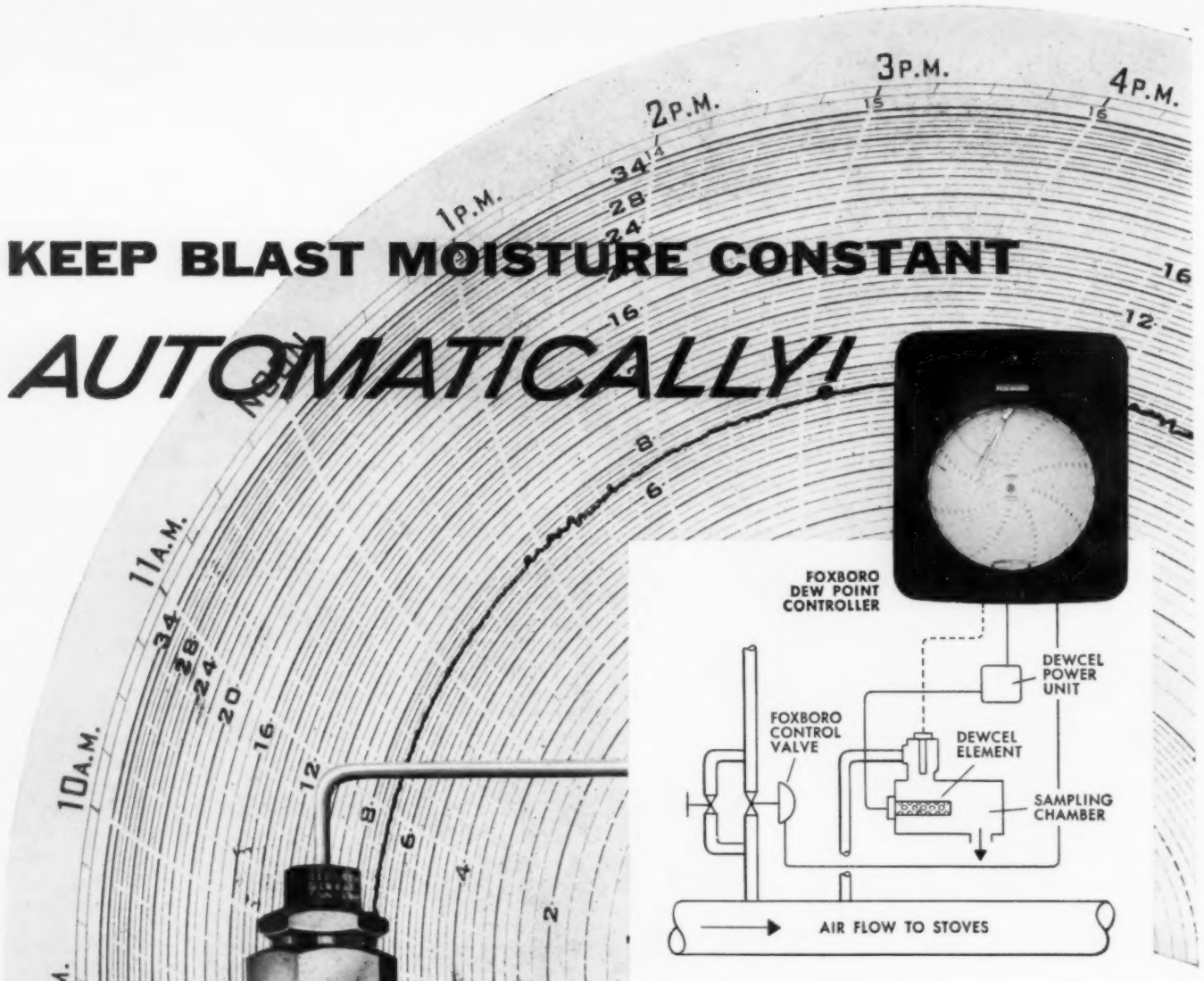
KEEP BLAST MOISTURE CONSTANT AUTOMATICALLY!



Section of Foxboro Dew Point Controller Chart showing typical moisture control record from actual installation. Control action automatically balances changes in atmospheric humidity.

The Foxboro Dewcel element is a highly accurate, rugged, moisture-sensing element designed for industrial use. It requires no water box — practically never needs attention.

You can eliminate moisture variations in blast air simply and economically with Foxboro Automatic Measurement and Control of blast dew point. This modern method employs the exclusive Foxboro Dewcel* element for measurement . . . eliminates water box and fan. The Controller maintains the correct, predetermined moisture value by regulating addition of steam to the blast. Blast moisture *automatically* remains constant despite the widest changes in atmospheric humidity. At the same time, moisture is recorded *directly*, accurately, in grains of water, on the Controller chart . . . a convenient supervisory record.

Foxboro Automatic Measurement and Control of blast dew point has already proved its value in over 50 installations through more stable furnace operation . . . better control of iron quality and uniformity. For full details, write for AED Sheet 330-1 and Bulletin 11-11. And, if you wish, a Foxboro Engineer will call to make recommendations for your furnace. **The Foxboro Company, 5912 Neponset Ave., Foxboro, Mass., U.S.A.**

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FOXBORO
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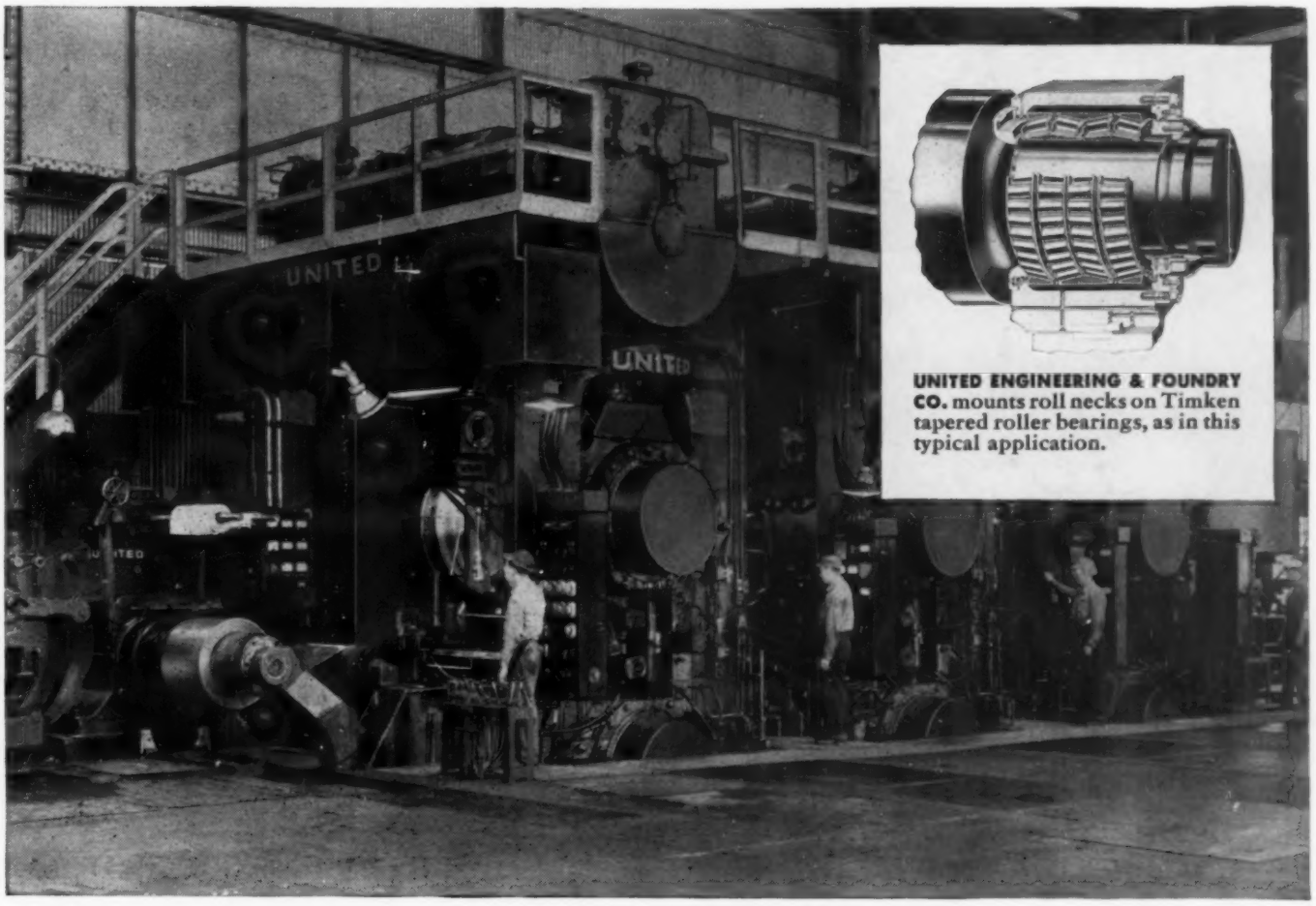
FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

AUTOMATIC CONTROL OF BLAST DEW POINT

Crucible Steel gets lower bearing cost per ton...less scrap loss per coil with roll necks on TIMKEN® bearings



UNITED ENGINEERING & FOUNDRY CO. mounts roll necks on Timken tapered roller bearings, as in this typical application.

UNITED ENGINEERING built this 3-stand tandem cold mill for Crucible Steel. Back-up rolls and work rolls are mounted on Timken® tapered roller bearings. By holding rolls rigid, Timken bearings assure "on-gauge" operation, cut costly scrap loss. And the long life of Timken bearings keeps bearing cost per ton of steel rolled to a minimum.

Tapered construction lets Timken bearings take radial and thrust loads. No extra thrust devices are needed. Chuck mountings are simpler, more compact. Timken bearings hold shafts, housings concentric — make closures more effective, with less lubricant leakage. Grease-lubricated Timken bearings require no tubes, pipes or reservoirs, reduce lubrication system maintenance costs. And rolls can be changed faster.

Geometrically designed and precision-made to give true rolling motion, Timken bearings permit easier acceleration, easier driving, which means a saving on power, reduced skidding and scuffing between rolls. Maintenance and repair costs are cut. Mills using balanced proportion Timken bearings increase roll neck strength up to 60% — load ratings up to 40%. The balanced proportion design permits large diameter roll necks without increasing bearing O.D., provides maximum capacity in less space.

Look for the trade-mark "Timken" on every bearing. The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

This symbol on a product means its bearings are the best.

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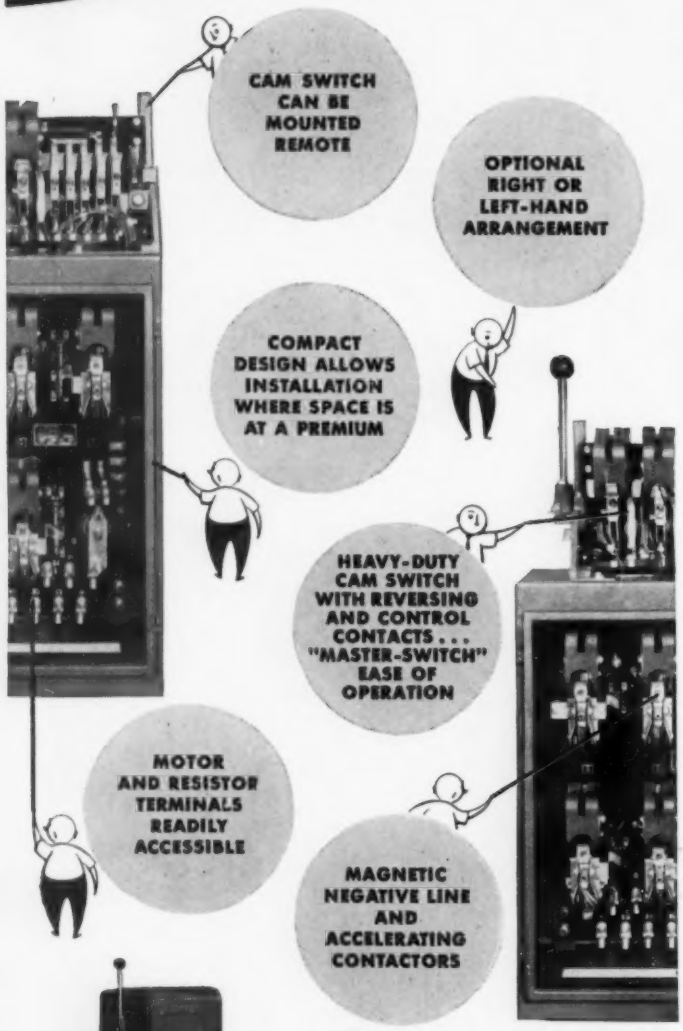
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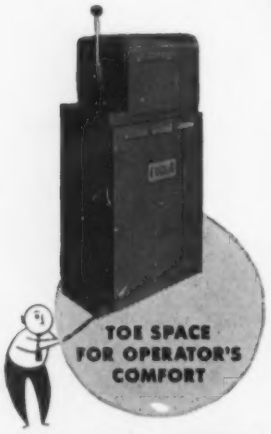

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Provide four speed points, reversing, with all advantages of full-magnetic control. Manually-operated cam contacts are free of destructive arcing . . . extremely fast magnetic contactor action interrupts power circuit before cam-operated contacts are opened. EUCLID'S EXCLUSIVE "TIMELOK" feature offers maximum dependable acceleration timing without extra relays . . . permits unusually compact arrangement of the magnetic panel.

For more information, contact our representative in your area, or write or call THE EUCLID ELECTRIC & MFG. CO., MADISON, OHIO.

Ask for Bulletin 4400-4401.

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Sub-micron fumes are the *really tough* problems in gas cleaning. These fumes cannot be economically or effectively controlled by conventional cleaning devices.

However, the CHEMICO P-A VENTURI SCRUBBER is proving its success in solving these *really tough* problems in more than 150 commercial installations and in more than 70 pilot investigations.

The table lists some of these commercial installations. All of these *really tough* problems and many more are being solved with complete satisfaction to users of P-A VENTURI SCRUBBERS.

PROCESS	DUST OR FUME	INSTALLED CAPACITY CFM
Incinerator—Flue Fed	Fly Ash	32,000
Incinerator—Sodium Disposal	Na_2O	9,000
Incinerator—Industrial	Radioactive Dust	6,000
Dry Ice & CO_2 Plants	Amine Recovery	72,400
CO_2 Gas for Process	Fly Ash	500
Boiler Flue Gas	Fly Ash & SO_2	4,300
Enamel Frit Furnace	Dust & HF	11,900
H_2SO_4 Concentrator	H_2SO_4	49,800
Copperas Roasting	H_2SO_4	34,250
Cobalt Ore Roasting	H_2SO_4	65,000
Chemico Wet Type Acid Plant	H_2SO_4	41,000
Chloro-Sulfonic Plant	H_2SO_4	600
Phosphoric Acid Plant	H_3PO_4	91,900
Phosphoric Acid Concentrator	H_3PO_4	194,000
Phosphor Copper Furnace	H_3PO_4	15,000
Smelting—Non-Ferrous		
Blast Furnace	Lead & Organic	12,000
Reverb. Furnace	Lead Compounds	23,500
Comb. Blast & Reverb.	Lead Compounds	7,000
Brass Furnace	Zinc Oxide	7,500
Ajax Furnace	Beryllium Fumes	4,000
Steel Plant		
Oxygen Steel Process	Iron Oxide	140,000
Blast Furnace	Coke & Iron Oxides	788,000
Zinc Sintering	Zinc Oxide	75,000
Wood Distillation	Tar Products	3,500
Na_2SiF_6 Dryer	SiF_4 & Dusts	700
Iron Chloride Concentrator	$FeCl_2$ & HCL Mist	40,000
Unknown	Carbon Black	1,700
Lime Kiln	Lime & Na_2O	18,000
Detergent Spray Dryer	Chemical Fume	250,000
Furfural Residue Burner	Fly Ash	36,000
Nodulizing Kiln	Manganese & Lead	25,000
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Write to our P-A Sales Department for Bulletins

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Save by using specialized refractories

Many refractories problems in metal-working furnaces have been solved *economically* by the use of B&W specialized refractory castables. Each ferrous or non-ferrous furnace application requires a specific combination of properties to meet the service conditions. Whether your problem is high temperatures, abrasion and erosion, slag attack or the need for insulation, to name a few, you will find the refractory castable best suited to your requirements in B&W's line. Shown here in digest form are data on the widely used B&W refractory castables for metal-working furnaces:

B&W Refractory Castables for Metal Working Furnaces

	Temp. F	PROPERTIES	TYPICAL APPLICATIONS
B&W Kaocast	3000	High resistance to spalling and slag attack. Low volume change and negligible reheat shrinkage.	Soaking pit covers, linings of high temperature heating and forging furnaces, burner blocks, electrode linings of electric furnace roofs, linings of non-ferrous metal furnaces.
B&W Kaocrete 32	3200	High strength, exceptional refractoriness, unusual volume stability, excellent resistance to spalling.	Can be used in applications similar to those of B&W Kaocast and where higher refractoriness is required.
B&W Kaocrete D	2500	Sufficient strength and hardness to withstand abrasion, considerable physical abuse and erosion.	Aluminum melting furnaces, linings and car tops in heat treating furnaces, as well as in sections of a wide variety of furnaces that are subject to scraping by hand tools or other mechanical abuse.
B&W Kaocrete A	2600	Resists reducing atmospheres. Has good resistance to erosion, abrasion and thermal shock.	Annealing furnace bases and other applications where resistance to reducing atmospheres is essential. Also as a general purpose castable for linings in medium temperature service.
B&W Kaocrete B	2300	Has an adhesive plastic texture particularly suited for vertical or overhanging constructions. Excellent for plastering.	Patching linings and baffles and for any application where plastering rather than gunning or casting is required.
B&W Kaocrete LI	2700	High alumina content, exceptionally high strength for resistance to abrasion and erosion.	Aluminum furnace linings where high alumina content is important.
B&W Kaolite 20	2000	Offers castable's fast, low cost installation plus insulation. Has refractoriness, light weight and low heat conductivity and, in addition, will resist reducing atmospheres. Can be poured or gunned.	Aluminum melting, heating and heat-treating, annealing and forge furnaces. Also for general maintenance and patching.
B&W Kaolite 22	2200	Has the same properties as B&W Kaolite 20. Can be used for higher temperatures but not in reducing atmospheres.	

Send for your copy of B&W Bulletin R-35. It gives additional information on B&W's versatile refractory castables.

B&W REFRACTORIES PRODUCTS: B&W Allmul Firebrick • B&W 80 Firebrick • B&W Junior Firebrick • B&W Insulating Firebrick • B&W Refractory Castables, Plastics and Mortars • B&W Silicon Carbide

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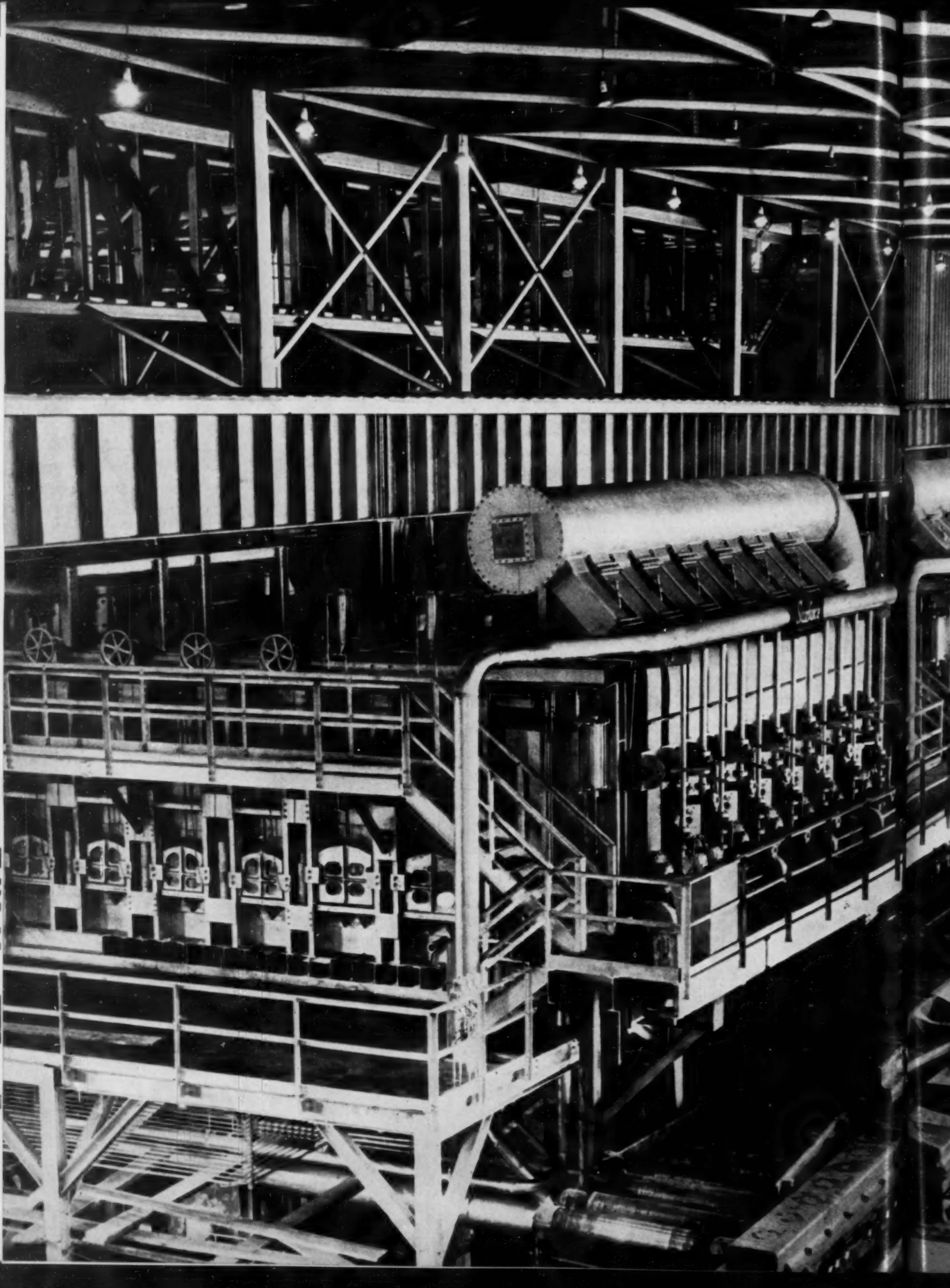
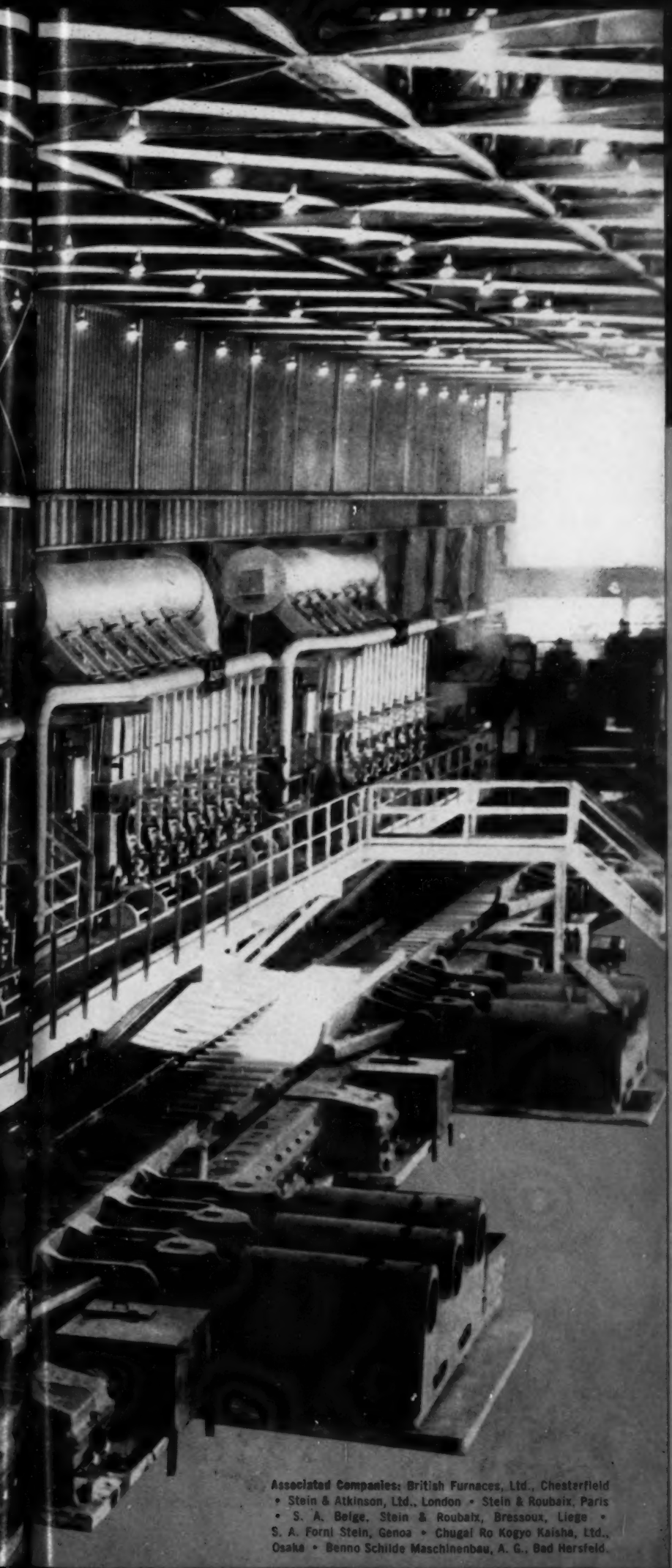
WORKS: AUGUSTA, GA.





Associated Companies: British Furnaces, Ltd., Chesterfield • Stein & Atkinson, Ltd., London • Stein & Roubaix, Paris • S. A. Belge, Stein & Roubaix, Bressoux, Liege • S. A. Forni Stein, Genoa • Chugai Ro Kogyo Kaisha, Ltd., Osaka • Benno Schilde Maschinenbau, A. G., Bad Hersfeld.

200 TONS AN HOUR CONTINUOUSLY

200 tons of steel slabs are heated to rolling temperature every hour, continuously, in each of these Surface monsters—world's largest slab furnaces.

No other furnace today can list all of these features:

1 Cantilever skid supports* permitting unobstructed combustion space for underfiring.

2 Furnace lines and burner design which provide high heat input from the moment the slab enters the furnace.

3 Built-in control* to prevent intermingling of gases from upper and bottom zones, providing better control of heat application, and preventing overheated slab end.

4 Anticipatory control which reduces temperature head when rate of slab discharge decreases.

5 Air preheat up to 1100°F.

6 Television signal to pusher pulpit, informing operator of the exact position of the leading slab.

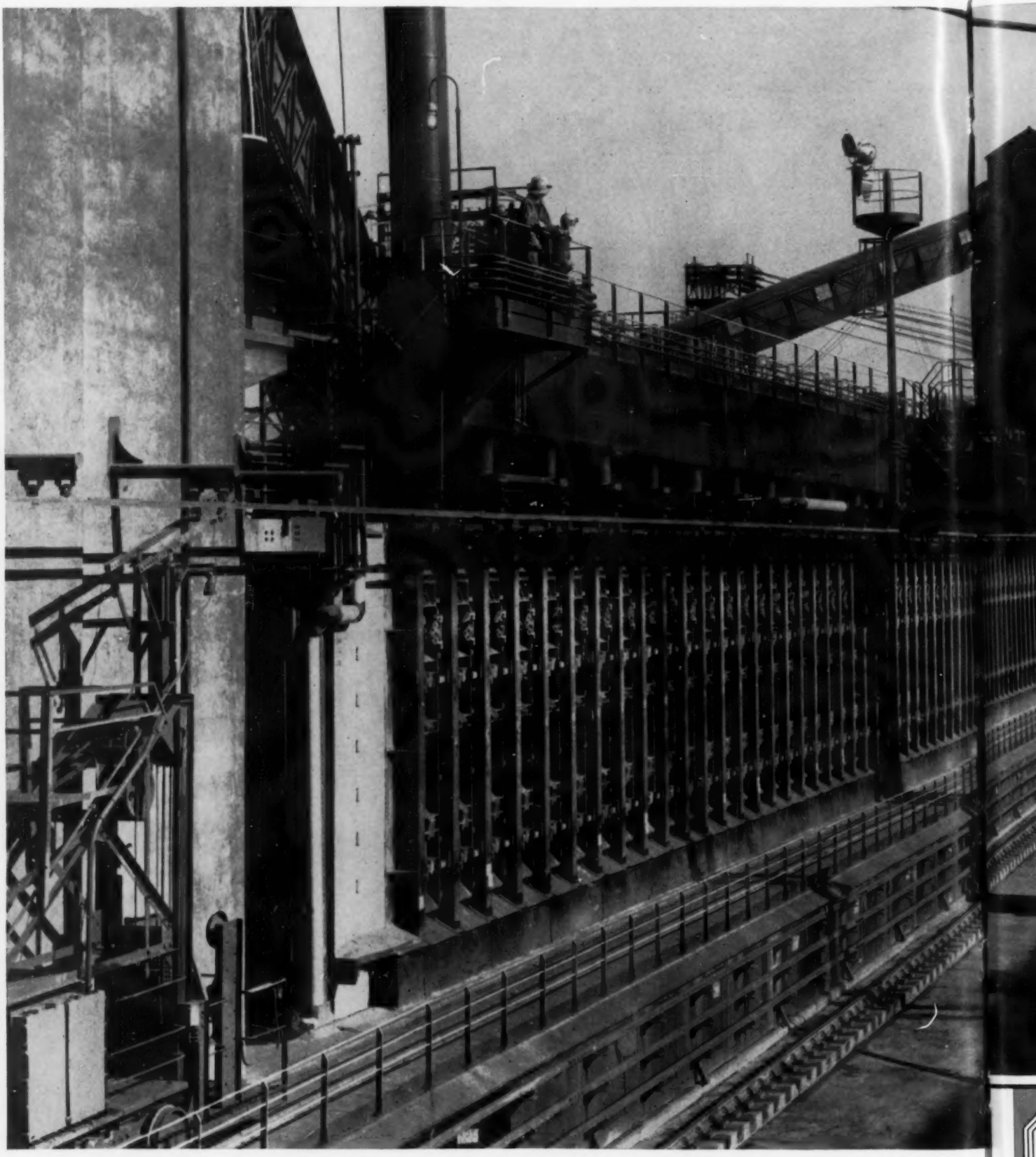
About the only conventional feature in these giants is the fact that the slabs are pushed in one end and out the other.

This is another demonstration that, at Surface, unconventional thinking and conventional experience are a productive team for the steel industry. Surface Combustion Corporation, Toledo 1, Ohio.

*patents pending

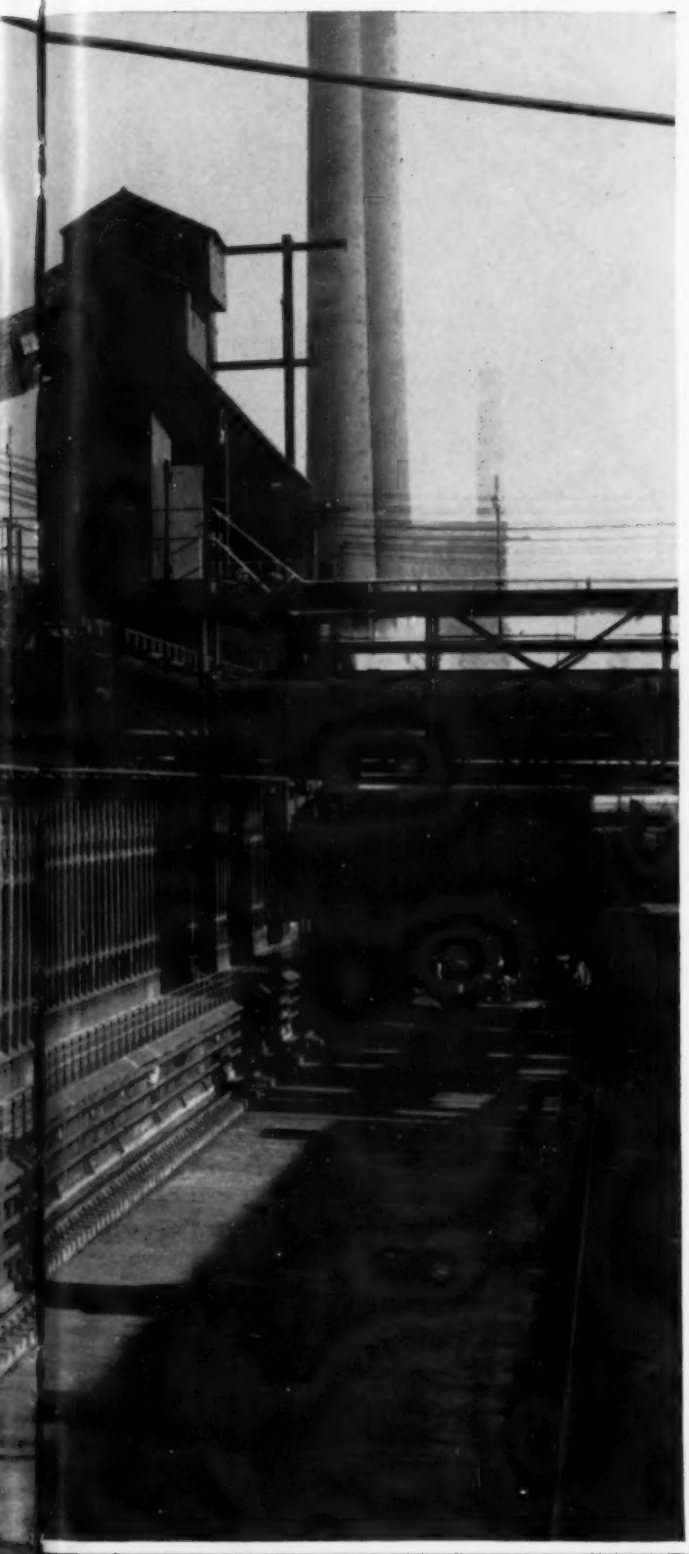
Surface
STEEL MILL EQUIPMENT

Inland Steel adds another battery of



Inland Steel's new battery of 87 Koppers-Becker Underjet Coke Ovens.

# of Koppers-Becker Coke Ovens



At Inland Steel Company's Indiana Harbor Works, this new battery of 87 Koppers-Becker Coke Ovens was put into operation during October of this year, and will carbonize 1,970 net tons of coal per day.

In this battery, the low-differential Koppers-Becker Underjet Coke Ovens are underfired with coke-oven gas. However, provision has been made for future underfiring with blast-furnace gas.

Each of these coke ovens is 40 feet, 1 inch long, 12 feet high and 18¼ inches in average width, with a 3-inch taper. The oven walls incorporate Koppers patented Hammerhead Construction.

These new coke ovens are similar in design to the battery of 65 Koppers-Becker Coke Ovens constructed in 1950. In fact, this new battery is part of Inland Steel's long-range program for meeting the ever-increasing demand for steel.

Designing and constructing coke ovens is just one way in which Koppers serves the steel industry. For any kind of metallurgical construction, **you can count on Koppers.** You are invited to consult with our Engineers and Management.

KOPPERS COMPANY, INC.
PITTSBURGH 19, PENNSYLVANIA

KOPPERS

KOPPERS

ENGINEERING AND CONSTRUCTION

The back-up roll bearings on this hot mill at U.S. Steel's Fairless Works are protected by Gulf I-C Oil—the oil that doesn't "break down" in rugged service, always maintains its excellent lubricating qualities, contributes to lower cost per ton rolled.

Tops in protection for back-up roll bearings

...GULF I-C OIL

Gulf I-C Oil has outstanding stability, resists emulsification and sludging, has excellent water separating characteristics. Bearings and oil lines are kept cleaner, when protected by Gulf I-C Oil —and bearings have longer life. Mill performance is more efficient. Maintenance costs are lower.

That's why scores of leading mills, like the one pictured here, prefer Gulf I-C Oil for safe, long-lasting lubrication of back-up roll bearings. Next time *you* order, specify the lubricant that contributes to lower cost per ton of steel rolled. Your Gulf Sales Engineer knows exactly which grade of Gulf I-C Oil is best for your operation. Just call your nearest Gulf office.

GULF OIL CORPORATION
GULF REFINING COMPANY
1822 Gulf Building
Pittsburgh 30, Pa.

GULF

THE FINEST PETROLEUM PRODUCTS FOR ALL YOUR NEEDS

Equipment News...

ALINEMENT DEVICE

▲ The jamming and breakage of gear-type alinement devices, common with grab buckets handling noncrushable materials, is entirely eliminated by a new link-type hinge alinement device developed by the Mead-

Morrison Division of the McKiernan-Terry Corp. The device has been specially developed for use on buckets handling slag, ore, and other extremely hard materials. In addition, the device has a great deal more bearing surface than an ordinary gear-tooth engagement and is entirely enclosed, reducing wear and lubrication problems, and decreasing maintenance.

The new device is fabricated entirely of Carilloy T-1 steel which has extremely high tensile strength and is unaffected by exposure to the high heats involved in handling hot slag. Operation is by the interaction of a linkage of T-1 steel plates that replaces entirely the gear-teeth of conventional hinge alinement devices.

ELECTRONIC ANALYZER

▲ Developed jointly by the Babcock & Wilcox Co., and the Bailey Meter Co., is an electronic system designed to analyze the operation of a giant steam generating unit in a few hours.

By means of "sensing" elements linked to analog scanners, the system can probe hundreds of different boiler locations. At the touch of a button, it begins gathering such data as temperature, pressure and gas composition. Complex electronic devices, operating without human guidance, then sort the information, supplement it with pre-set figures, and punch it in code on continuous tape.

Tape readings are transmitted by teletype to New York City, where B & W has a large electronic computer. Translated automatically into code suitable for computer use, the information is processed mathematically and transmitted back to the boiler site for application by engineers and technicians.

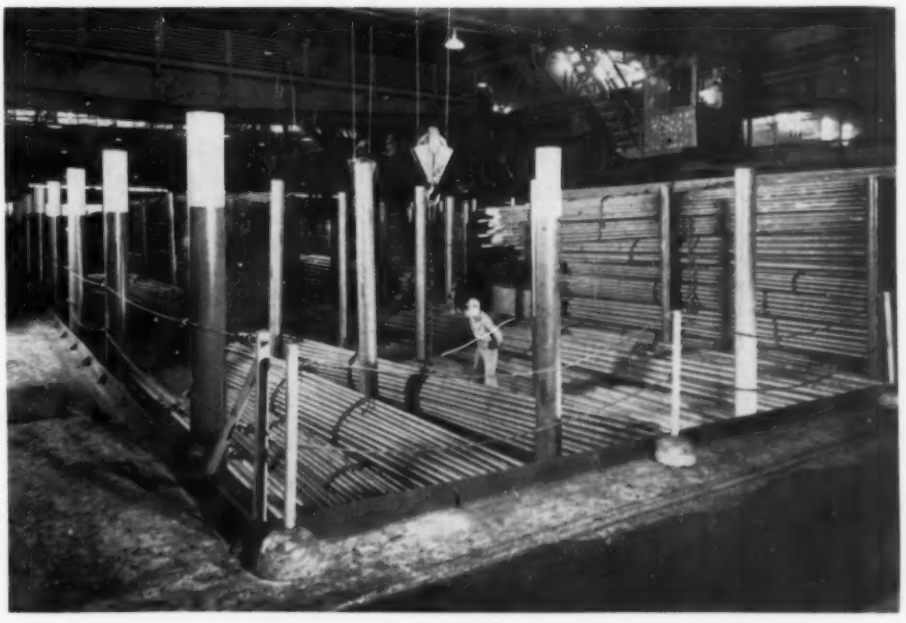
The new system has been developed to help engineers determine quickly and economically such boiler problems as sources of heat losses, the most efficient types of fuels, and when and where to remove combustion waste deposits. Emphasizing the need for a method of correcting material or operating faults promptly, B&W authorities pointed out that boiler malfunctions and abnormal fuel consumption may continue for weeks under ordinary trouble-shooting methods. They said that the system also represents an effort to conserve critically short engineering manpower by reducing the number of personnel and the amount of time required to conduct boiler analyses.

The "brain" of the system is a centrally located electronic coordinating unit developed at the B&W Research Center at Alliance, Ohio. A special "scanning" device created by Bailey Meter makes it possible for the system to gather data from widespread points of a boiler. Each scanning unit collects information from 25 different sensing elements. Any number of these devices may be hooked up with the system, depending on the quality and location of points from which information is desired.

Potentials of the new equipment will be more fully realized when it is

SPANG-CHALFANT SOLVES STORAGE PROBLEM

In-plant storage space at National Supply Co.'s Spang-Chalfant Division, Ambridge, Pa., could not be expanded upward or outward because of overhead crane clearance requirements and floor space limitations. The problem was solved by digging into the ground for 40 per cent increases in several locations. More than 120,000 cu ft of additional space was provided for seamless pipe in four storage areas where concrete-lined pits five ft deep increased piling height to 13½ ft. The enlarged areas are as compact as before, permitting increased production efficiency without plant expansion and without affecting handling methods. Separation of various types and sizes of pipe is provided conventionally by posts, spaced to mark off 8 by 12-ft areas.



Red Circle Rolls for all Purposes

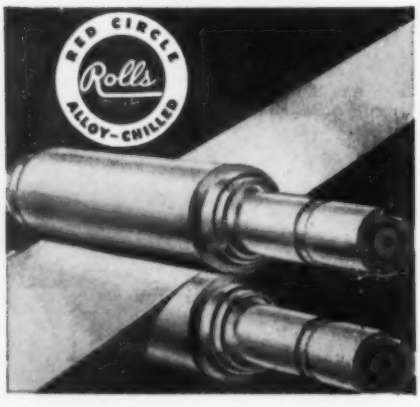
The Red Circle on the Roll is the Hyde Park mark of Quality. Hyde Park makes rolls for every type mill.

Chilled Rolls
Alloy Iron Rolls
Moly Rolls
Nickel Chilled Rolls
Grain Rolls
Cold Rolls
Sand Rolls

for
Finer Finish, Longer Life
and Greater Tonnage
specify Red Circle

Hyde Park

FOUNDRY & MACHINE CO.
Hyde Park, Westmoreland County, Pa.
ROLLS • ROLLING MILL MACHINERY
GREY IRON CASTINGS



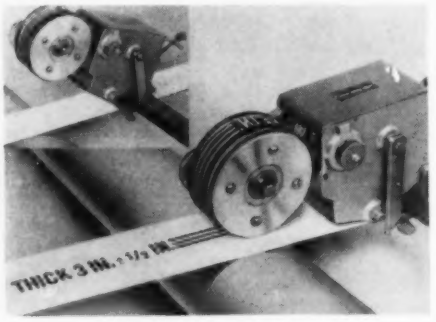
applied later this year to the first of three steam generating units of a new type being built by B&W.

Spokesmen for Bailey Meter, which plans to make the new equipment available commercially if it proves successful, said that the system has been designed primarily for the analysis of large steam generating units. They added, however, that it should be adaptable to smaller boilers or boiler elements, and capable of being moved readily from one boiler to another.

In future tests, officials of the two companies revealed, the system will be applied not only to boilers, but to a broad range of equipment used in conjunction with them. They said that the system may shed new light, for example, on the combined operating efficiency of turbines and auxiliary equipment used to produce and distribute electric power.

AUTOMATIC PRINTER

▲ A mechanical printing device that prints up to 1¼ in. character size (standard unit) of continuous reading or repeat codes, dates, trademarks, etc. on any printable surface has been announced by Pannier



Corp. Known as the "super ink print-all," this device solves the problem of light colored, heavy pigmented ink printing that has been impossible with internally fed inking rolls.

This printing device can be mounted to mark either side of material moving on horizontal or vertical conveyor lines and it repeats on 12 in., 18 in., or 24 in. cycles or any other cycle within this range.

The super ink print-all uses inks from semi-paste to light liquid and all consistancies in between. Tank type ink well allows continuous operation because shutdown for refilling is eliminated.

While it is normally friction driven, it can be supplied for direct drive from your conveyor; with the instal-

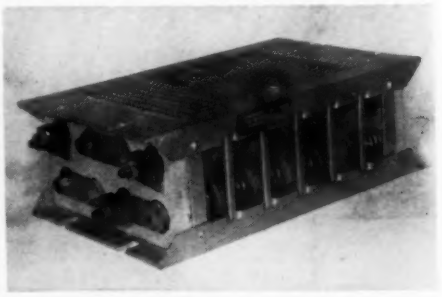
GUYAN
RESISTORS

Engineered and designed to eliminate resistor maintenance on troublesome mill applications.

Non-breakable helical coil construction ends burnouts due to warping and buckling of grids.

Sturdy, rugged steel construction eliminates shock and vibration troubles.

Custom designed for your conditions including excessive graphite accumulations.



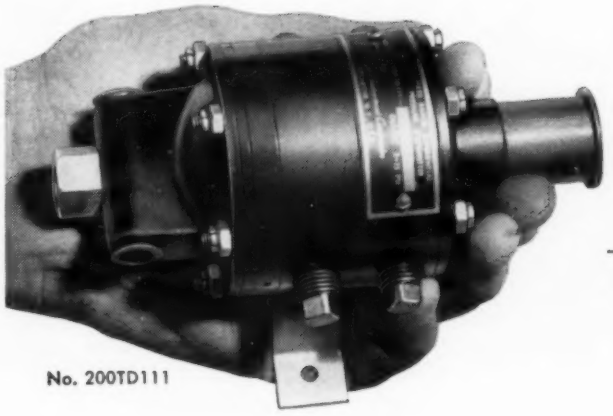
With a quarter century of resistor engineering, we invite you to take advantage of our experience.

For complete information on Guyan Resistors, please contact the nearby Guyan Representative or our main plant at Logan, W. Va.

Baltimore, Md.—Durling Electric Co., 2505 St. Paul St.
Birmingham, Ala.—Ebbert & Kirkman Co., 2313 6th Ave. So.
Buffalo, N.Y.—Buffalo Electric Co. West Mohawk St.
Chicago, Ill.—John K. Byrne, 1515 W. Howard St.
Cleveland, Ohio—Mechanical Equipment Co. 3100 Prospect Ave.
Detroit, Mich.—Plant Equipment Co., General Motors Bldg.
Philadelphia, Pa.—George I. Wright 811 Commercial Trust Bldg.
Pittsburgh 27, Pa.—P. R. Holden, 4860 Elmwood Dr.

GUYAN MACHINERY COMPANY
LOGAN, W. VA.

"That new Taylor Instrument's saving us money already!"



No. 200TD111

He's talking about the new Taylor low-cost Flow Transmitter!

THE reason he can spot the savings so quickly is that the No. 200TD111 Fixed Range Differential Pressure Transmitter is being used to measure departmental consumption of steam, air and water that previously went unchecked. That 3-pen recorder in the background shows at a glance how much is being used by a given department as a basis for apportioning costs. It's the remarkably low price of this new instrument that makes it such a practical cost accounting aid on applications hitherto considered marginal.

Measuring only 6½" x 3" and weighing only 4½ lbs., its simplified piping, force-balance construction and external adjustments make it easy to install and maintain. Calibration accuracy is better than 1%. Sensitivity exceeds 0.1%. Ranges 0 to 50, 100, 200 and 300 inches of water. Built for rough service and outdoor mounting.

Call your Taylor Field Engineer, or write for **Bulletin 98274.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

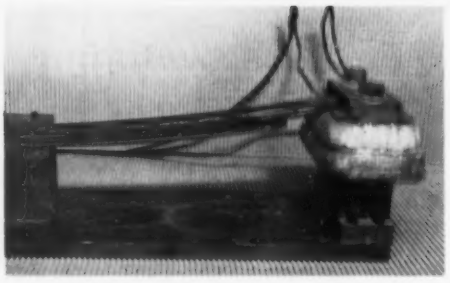
DESIGN SPECIFICATIONS

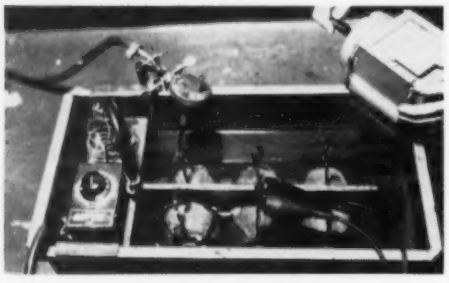
Diaphragm of Neoprene-impregnated Nylon.
Body material, brass.
Maximum working pressure: 150 psi.; temperature 150°F.
Air Supply pressure, 20 psi.
Air consumption, 0.10 standard cu. ft. per minute.
Output pressure range 3 to 15 psi.
Size 6½" x 3". Weight 4 lbs. 9 ozs.
All connections ¼" internal NPT.

Taylor Instruments
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY

for longer life and more reliable performance, use

National Polyester Moulded Field Coils





INCREASED STRENGTH

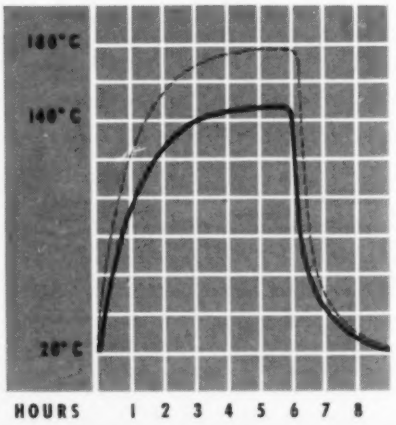
Complete polyester filling bonds all parts of the coil into a strong, unified, shock-resistant construction. The photograph at the left shows a shock test in which an energized and heated coil has been striking an anvil once a second for six months with no adverse effects.

GREATER RESISTANCE TO CORROSIVE ENVIRONMENTS

Complete polyester filling prevents penetration of moisture, oil, conducting dust, and other foreign matter that contribute to coil failures. The photograph at left shows a test in which National polyester coils were immersed successively in water, hot oil, and an iron filing solution. Periodic resistance tests show *no deterioration* of the insulation after several months submersion.

COOLER OPERATION

Absence of voids in the coil enhances heat transfer. The graph below shows comparative heating and cooling cycles for polyester-filled (solid line) and conventional varnish-treated (dotted line) field coils carrying the same amperage.



National polyester-filled field coils can be installed in National service shops or supplied for installation by your own motor maintenance crews. Call your nearby National field engineer or write for details.

NATIONAL ELECTRIC COIL COMPANY

COLUMBUS 16, OHIO, U. S. A.

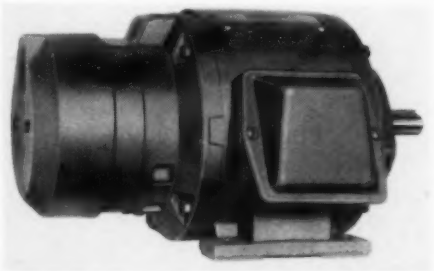
ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION—REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

lation of timing mechanism, it will clearly mark, in register, bags, cartons, and packages (even cellophane).

BRAKEMOTORS

▲ A new line of rugged, cast-iron brakemotors that stop instantly and hold heavy loads have been announced by Reliance Electric & Engineering Co.

Features include a wide torque range from 3 lb-ft to 345 lb-ft, one piece molded friction linings for



quick stops, and one-operation torque setting. In the event of power failure or low voltage, "dead man" operation sets and holds the load until normal operation is restored. The design incorporates a minimum of wearing parts, and any adjustments may be performed easily with ordinary tools by simply removing the brake housing and lifting out the entire operating mechanism.

SPOT WELDING ACCESSORY

▲ A new semi-automatic spot and tack welding accessory, suitable for use with all models of its semi-automatic wire drive unit, has been announced by General Electric Co.

Available in kit form or as a factory installed accessory on current models, the set consists of a gun adaptor kit and control. The gun kit includes locating plates for butt, corner, and fillet welds, and can also be adapted for other configurations.

The controls are mounted permanently on a steel door that replaces the standard door on the wire drive unit. The control door is mounted on existing units by ordinary metal screws, and leads wired into the existing circuit.

The gun adapter kit consists of a screw-on nozzle and two sets of locating plates for the three basic weld positions. Also furnished are protective plates so that the operator does not need to wear a protective helmet or glasses.

Control for the unit consists of a timer, which can be set for welding times of from 8 to 360 cycles; an on-off switch for the timer; and a slow-fast switch for the speed with which the wire drive is started. With the slow start setting, the striking of the arc immediately brings the wire drive to normal speed. This feature can be used regardless of whether the spot welding attachment is in use.

In the control circuit are the pneumatic time delay relay, the on-off and slow-fast start switches, and a current pick-up relay.

TEMPERATURE REGULATOR

▲ A new safety-type temperature regulator has been added to the line of self-powered control instruments manufactured by the Fulton Sylphon Division of Robertshaw-Fulton Controls Co.

Designated the No. 997 temperature regulator, it will close auto-

Pure Copper Castings

Tuyeres • Tuyere Coolers
Cinder Notches
Valve Gates and Seats

Brass and Bonze Castings

(Heavy type—1 to 2 ton)
Bearings • Machinery Bronze
Bars and Bushings

Lawrence Tuyeres are precisely cast to fit smoothly and snugly into the cooler. At installation this saves both time and additional machining costs so often necessary with less expertly made Tuyeres. Since 1888 many of America's large steel mills have continuously used Lawrence Tuyeres for their high quality and complete dependability. Try Lawrence Tuyeres in your blast furnaces. You'll appreciate what their neat fit and high quality means in terms of easy installation and longer life. When in the market, try Lawrence Tuyeres. Write today.

LAWRENCE COPPER & BRONZE CO.

ZELIENOPLE, PA.

BOX 246 PITTSBURGH DIST. PHONE 774

matically to prevent overheating and possible damage to products in process, in the event the thermostatic unit is accidentally damaged.

The No. 997 contains a large 4⅝ in. bellows for more powerful response and smoother modulating action in controlling the flow of steam, hot water or other medium. Because the No. 997 has a special tight-closing, single-seated valve, it is suitable for "dead end" or terminal service. It is available in sizes from ¼ in. to 2 in.

Another feature of the new regulator is a heavy gage stainless steel frame.

MOLYBDENUM PELLETS

▲ Molybdenum pellets of high purity and high density are now being produced in quantity by Sylvania Electric Products Inc., it has been announced by the company's Tungsten and Chemical Division.

The new pellets are designed specifically for vacuum melting processes used in the manufacture of critical high-temperature alloys.

Of an easy-to-handle size, approximately 1 in. in diameter by ½ in. high, these molybdenum pellets meet the need for inexpensive, highly uniform molybdenum in vacuum melting. The pellets are approximately 99.85 per cent pure molybdenum, with a density of 7.0 grams per cu centimeter, and a gas content in the range of 300 ppm, well below the 400 ppm considered suitable for vacuum melting.

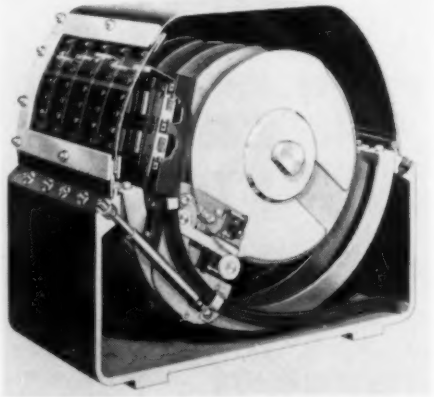
CAM LIMIT SWITCH

▲ A new rotating cam limit switch with 15-amp contacts, especially designed to facilitate precise synchronization of multiple operations, has been developed by the Clark Controller Co.

The switch features a positive micrometer screw adjustment of each individual switch mechanism in relation to its cam. This adjustment can be made with a screwdriver, from the outside, while the switch is in motion.

The cam limit switch is made in three standard sizes accommodating up to five, nine, or 12 cams. The split butterfly cams can be set with a spread between circuit make and break of from 15 to 345 degrees, and the external in-motion adjustment of plus or minus 15 degrees makes possible micro-adjustment while equipment is in motion.

Contact assemblies may have two sets of contacts, one normally-closed and the other convertible — either normally-open or normally-closed.

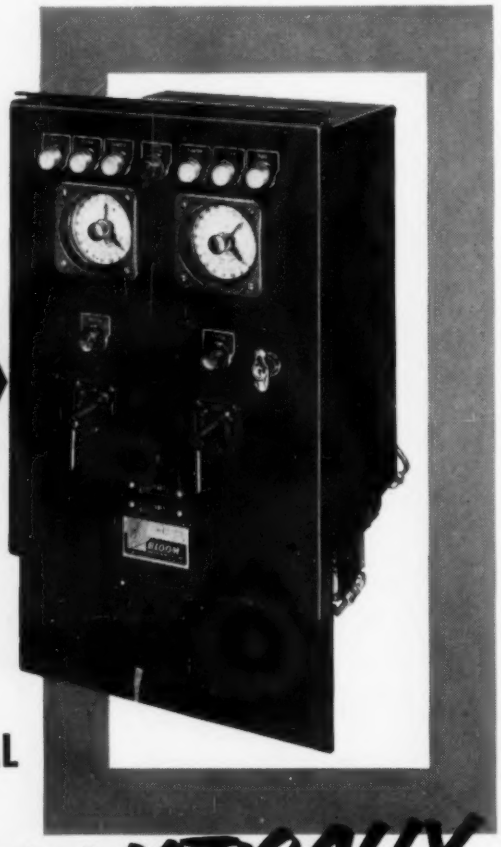


Contact operating arms bearing on the cams have nylon rollers which virtually eliminate wear. Both fixed and moving contacts can be inspected from the outside through a transparent panel in the oiltight case.

Cams are individually adjustable and removable without disturbing other cams. Contacts can be removed and replaced without disassembling the switch.

The switch is designed to operate at speeds up to 100 rpm, and rotation can be either clockwise or counterclockwise.

The BLOOM Time-Cycle Reversal Unit

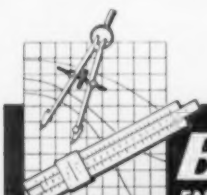


assures FULL, FAST AND EFFICIENT REVERSAL OF REGENERATIVE FURNACES AUTOMATICALLY

This complete, compact, factory-tested unit provides a combination electric-pneumatic system for Open Hearth Furnace and Soaking Pit reversal. It eliminates reversal puffing and shortens reversal period. (10 to 15 seconds easily accomplished).

Shorter reversal cycle improves furnace life.

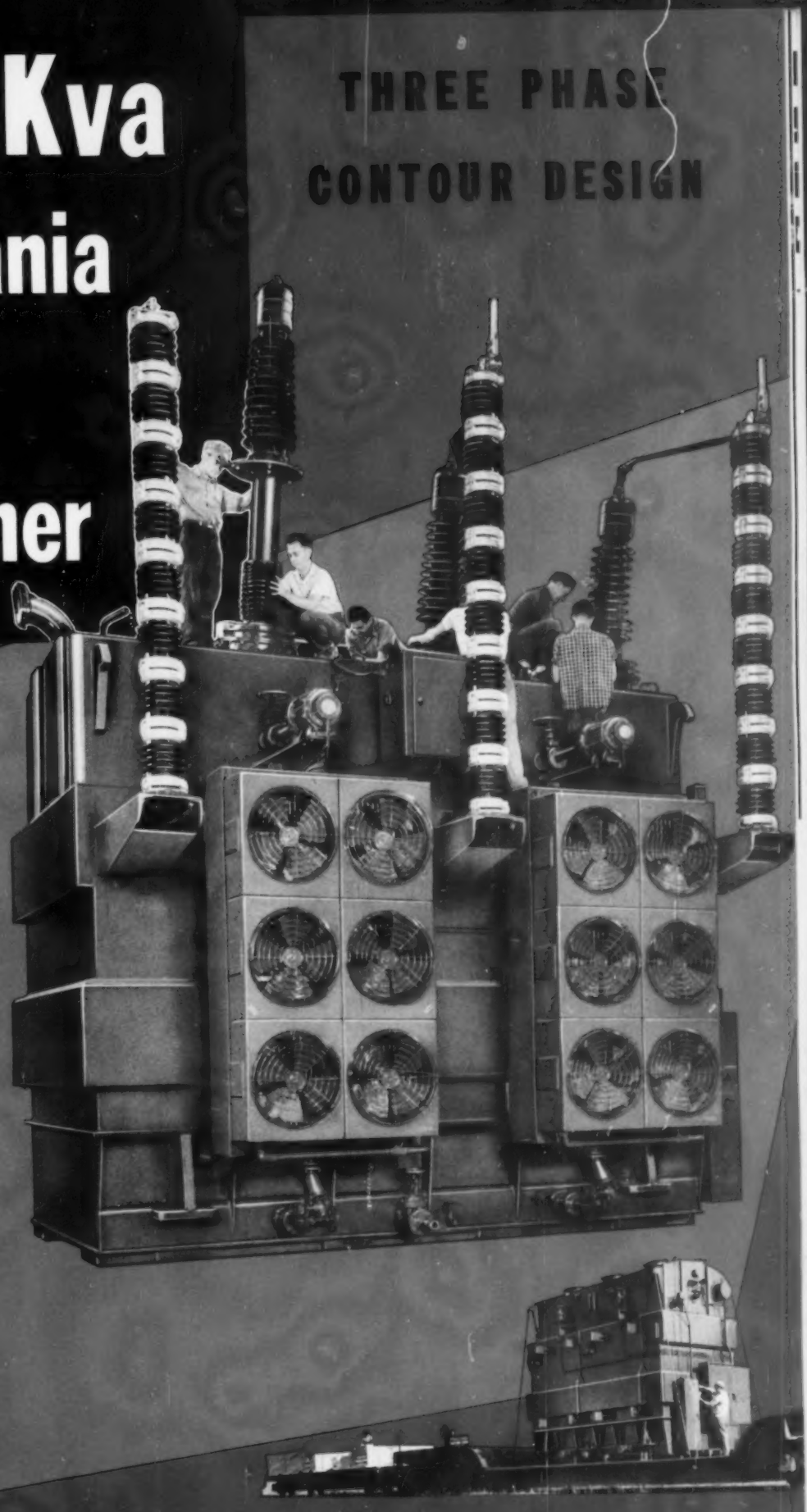
These units have been in continuous service for nine years. Trouble-free maintenance.



BLOOM ENGINEERING CO., INC.
857 W. North Avenue Pittsburgh 33, Pa.

WRITE or phone for complete information on the Bloom Time-Cycle Reversal Unit.

140,000 Kva Pennsylvania Power Transformer



140,000 Kva, 115 Kv, is the rating of this main step-up generating station transformer. Completely assembled except for bushings and coolers, it traveled by train to its destination in an upright position. This simplified the matter of installation and saved time and money for the utility. Pennsylvania's space-saving, shell form, Contour Design construction made this type of shipment and installation possible. Although it has a large Kva capacity, only 9000 gallons of oil are required to cool the transformer through four oil-to-air heat exchangers.

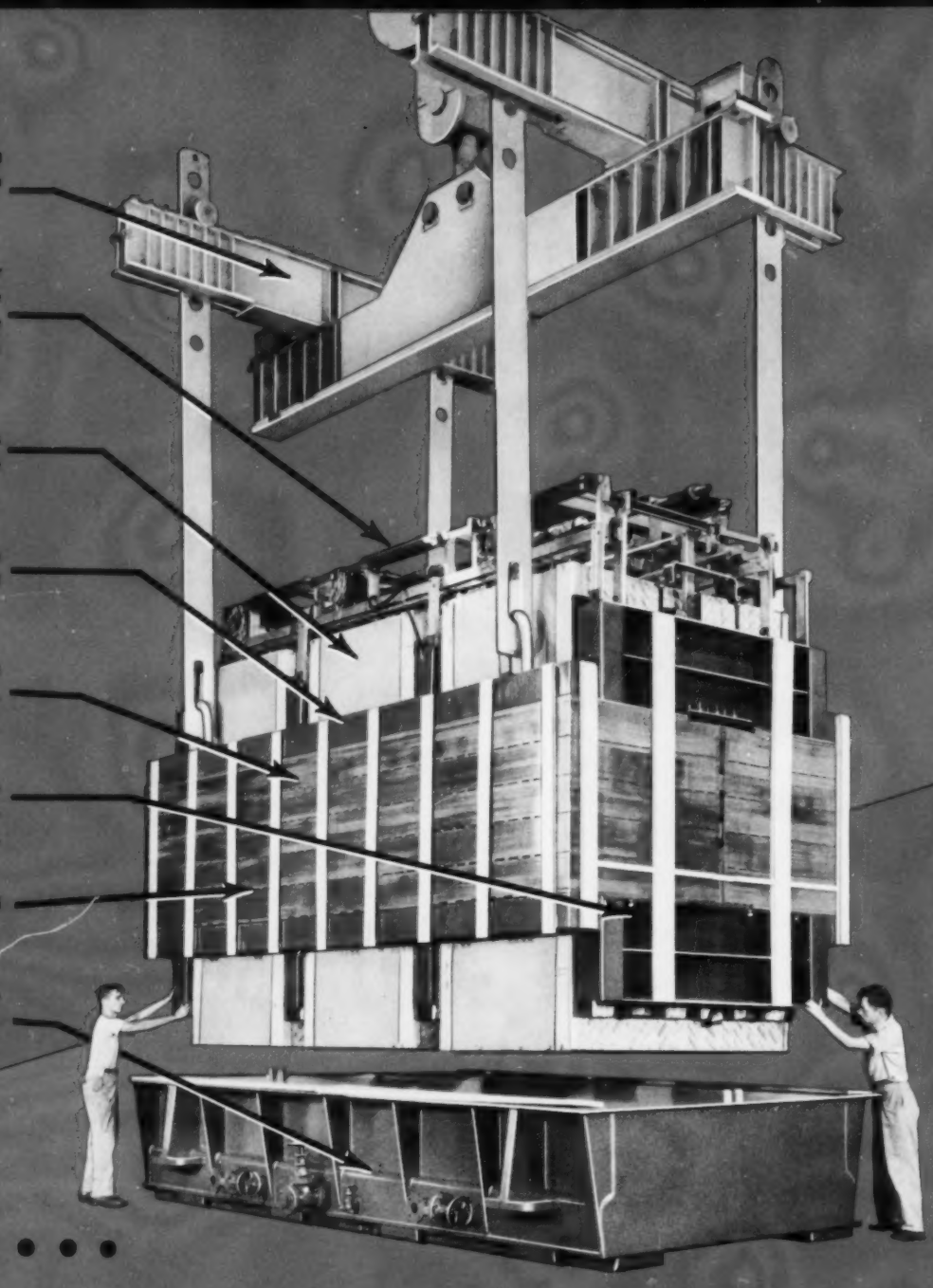
pt

PENNSYLVANIA TRANSFORMER COMPANY

A McGraw Electric Company Division

CANONSBURG, PENNSYLVANIA • *Greater Pittsburgh District*

SEE NEXT PAGE
FOR INSIDE STORY



Core and coil assembly being lowered into bottom tank section by Pennsylvania's 165-ton crane.

Straight line tap changer with silver alloy contacts is located above the core and coils where it is accessible through manholes for inspection and maintenance.

Vertical cooling ducts in the coils permit a free flow of oil through the coils for most efficient cooling.

Core and coils clamped together with heavy steel frames to form a rigid structure.

Core and coil unit can be handled separately as a complete sub-assembly.

Heavy box sections form part of core frame and clamp coils against mechanical forces during short circuits.

Core cooled by both vertical and horizontal ducts.

Core and coil assembly rests on bottom section of Contour Design tank.

Inside a . . .

140,000 Kva THREE PHASE CONTOUR DESIGN

Pennsylvania Power Transformer

140,000 Kva, Three Phase, 60 Cycles, 55° C. Temperature Rise.
High voltage: 115,000 Grd.Y/66,400 volts. Low voltage: 14,700Δ volts.

PENNSYLVANIA TRANSFORMER COMPANY

A McGraw Electric Company Division

CANONSBURG, PENNSYLVANIA • *Greater Pittsburgh District*

For exterior view of this transformer, see other side.

HIGH PRESSURE CLEANER

▲ A new high pressure cleaner has been announced by Homestead Valve Manufacturing Co. By simply setting valves on the control panel, the operator can get any desired cleaning action ranging from 400 gphr of clear cold water at 450 lb pressure, up to a mixture of steam, water and cleaning compound at 325 F.

Many combinations of heat, pressure, and water volume, with or without cleaning compound, enable the unit to do such diversified jobs as blasting heavy mud or clay deposits from trucks, road-building or construction machinery; removing grease and dirt from equipment, machinery, parts, floors, etc.; cleaning for repainting; or doing a thorough job of sanitizing or deodorizing.

Book Reviews

"Radioisotopes the Wonder Tool," Walter A. Shead, Editor-in-Chief, published by Vincent F. Callahan and Frederick Hollowell, is available from The Atomic Energy Guideletter, 1420 New York Avenue, N. W., Washington 5, D. C. The book contains 90 pages, 8½ x 11 in., heavy paper bound, sells for $7.50. This book presents the uses, techniques and applications of radioisotopes to industrial and other processes which can effect tremendous savings annually to industry. The book touches only the agricultural and medical field. Such phases are discussed as purchasing, how, where, regulations; regulations affecting commercial suppliers; comparison of high voltage machine radioisotopes and those produced from nuclear reactors; and many other factors.

"Engineering Inspection Measurement and Testing," by H. C. Town and R. Colebourne has recently been published by the Philosophical Library, 15 East 40th Street, New York 16, N. Y. The book contains 192 pages, 6 x 9 in., is cloth bound, and sells for $8.75. This is an up-to-date work on modern methods of measurements and testing, and after first explaining the function of the modern factory inspection department and briefly tracing the development to presently recognized standards and methods of measurement, the book deals with the principles and practice of precision measurement. It also covers comparators and other measuring and inspection machines with special attention given to measurement during machining and automatic sizing operations, to screw-thread measurements, and devotes a chapter to the measurement of surface finish. More than 200 illustrations explain and supplement the text, thus offering a book of practical interest to all engineers engaged in precision measurement and inspection.

"Metallurgy" (fourth edition) by Carl G. Johnson and William R. Weeks has recently been published by American Technical Society, 848 East 58th Street, Chicago 37, Ill. The book contains 454 pages, 8½ x 5½ in. is cloth bound, and sells for $5.50. This is a practical survey text stressing the importance of the physical and chemical properties of metals for shaping, sizing, and fabricating metal products, presenting the principles and practices governing the selection, testing, and treatment of metals and their practical application to the problems of design and production. This copy contains modern, practical information on the extraction of metals from their ores, refining and alloying operations. The equipment used and methods of making microscopic examinations are discussed in easy-to-understand language. The fourth edition is greatly enlarged, and, also adds information on bearing alloys, aluminum alloys, alloy steel, copper and copper alloys, cast iron, and heat treatment.

"Oxidation Resistant Silicon Aluminum Steels" (Special Report No. 2) by E. A. Brandes, was recently published by Fulmer Research Institute, Limited, Stoke Poges, Buckinghamshire, England. The book contains 40 pages, 9½ x 7½ in., bound in heavy paper, and sells for 10/6d net. The report covers the preparation of the alloys; and data from corrosion tests and on mechanical properties of various silicon-aluminum steels. Photographs, curves and tables substantiate and explain the text.

"Symposium on Impact Testing" (ASTM Special Technical Bulletin No. 176), a report of the symposium, sponsored by Committee E-1 on Me-

(Please turn to page 232)

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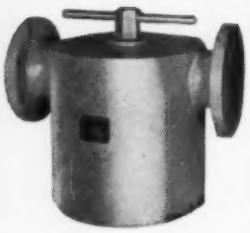

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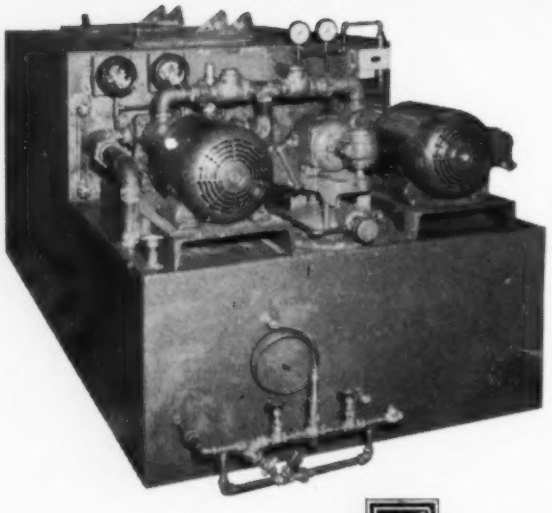

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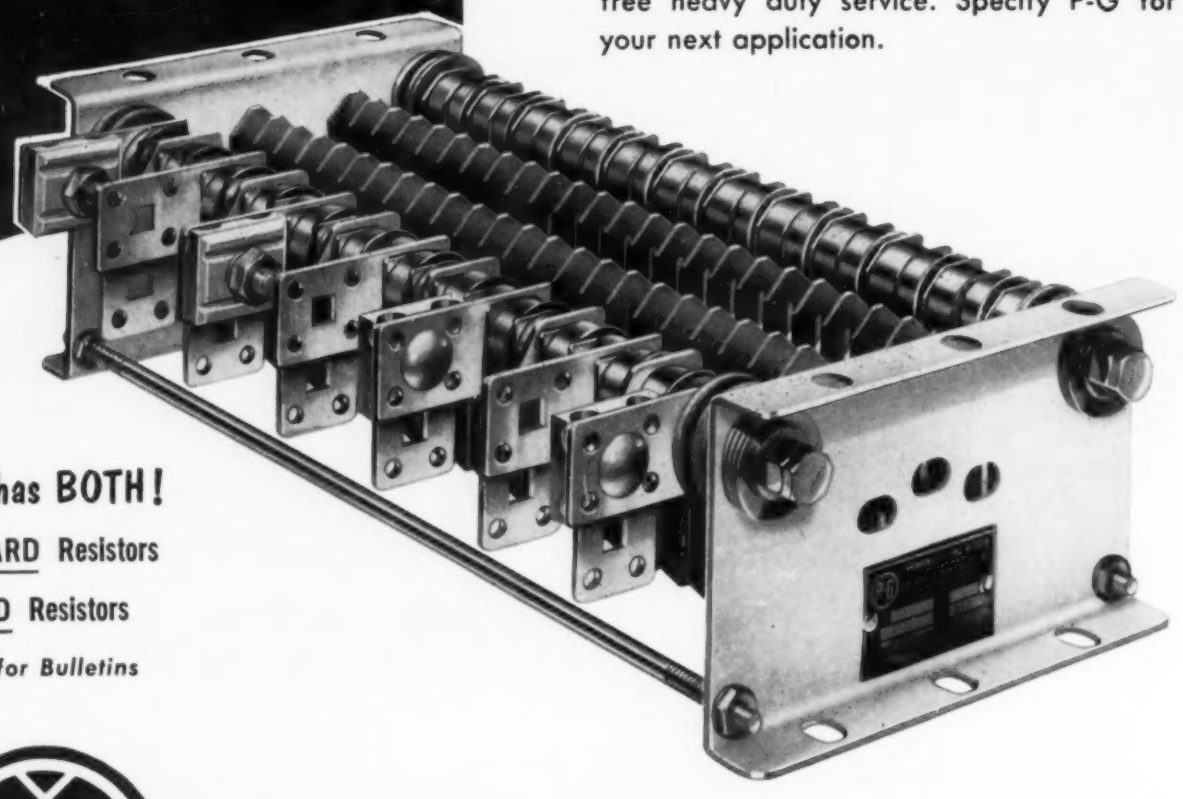

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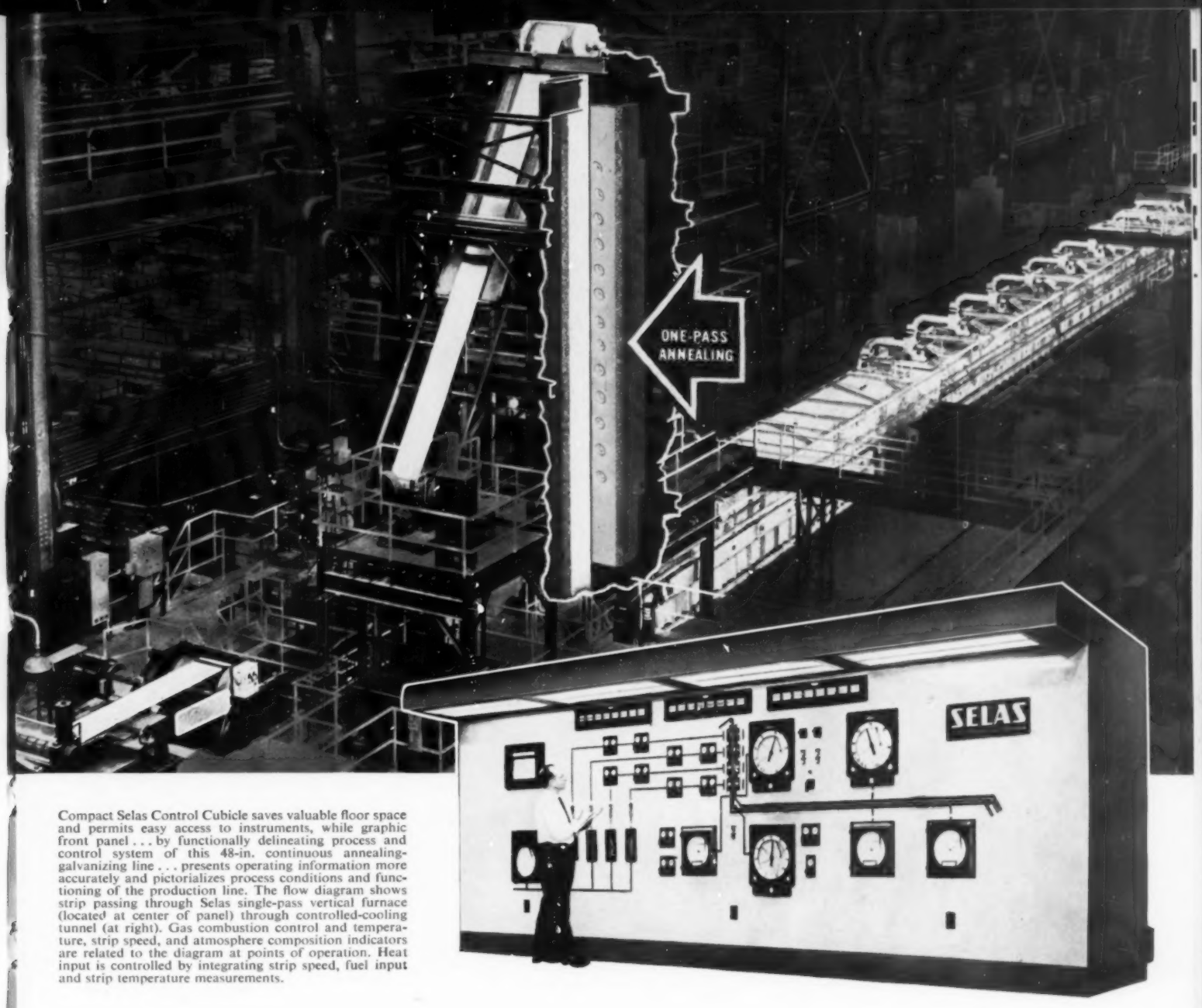

Compact Selas Control Cubicle saves valuable floor space and permits easy access to instruments, while graphic front panel . . . by functionally delineating process and control system of this 48-in. continuous annealing-galvanizing line . . . presents operating information more accurately and pictorializes process conditions and functioning of the production line. The flow diagram shows strip passing through Selas single-pass vertical furnace (located at center of panel) through controlled-cooling tunnel (at right). Gas combustion control and temperature, strip speed, and atmosphere composition indicators are related to the diagram at points of operation. Heat input is controlled by integrating strip speed, fuel input and strip temperature measurements.

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- Elimination of externally-prepared atmosphere in heating section reduces operating costs.
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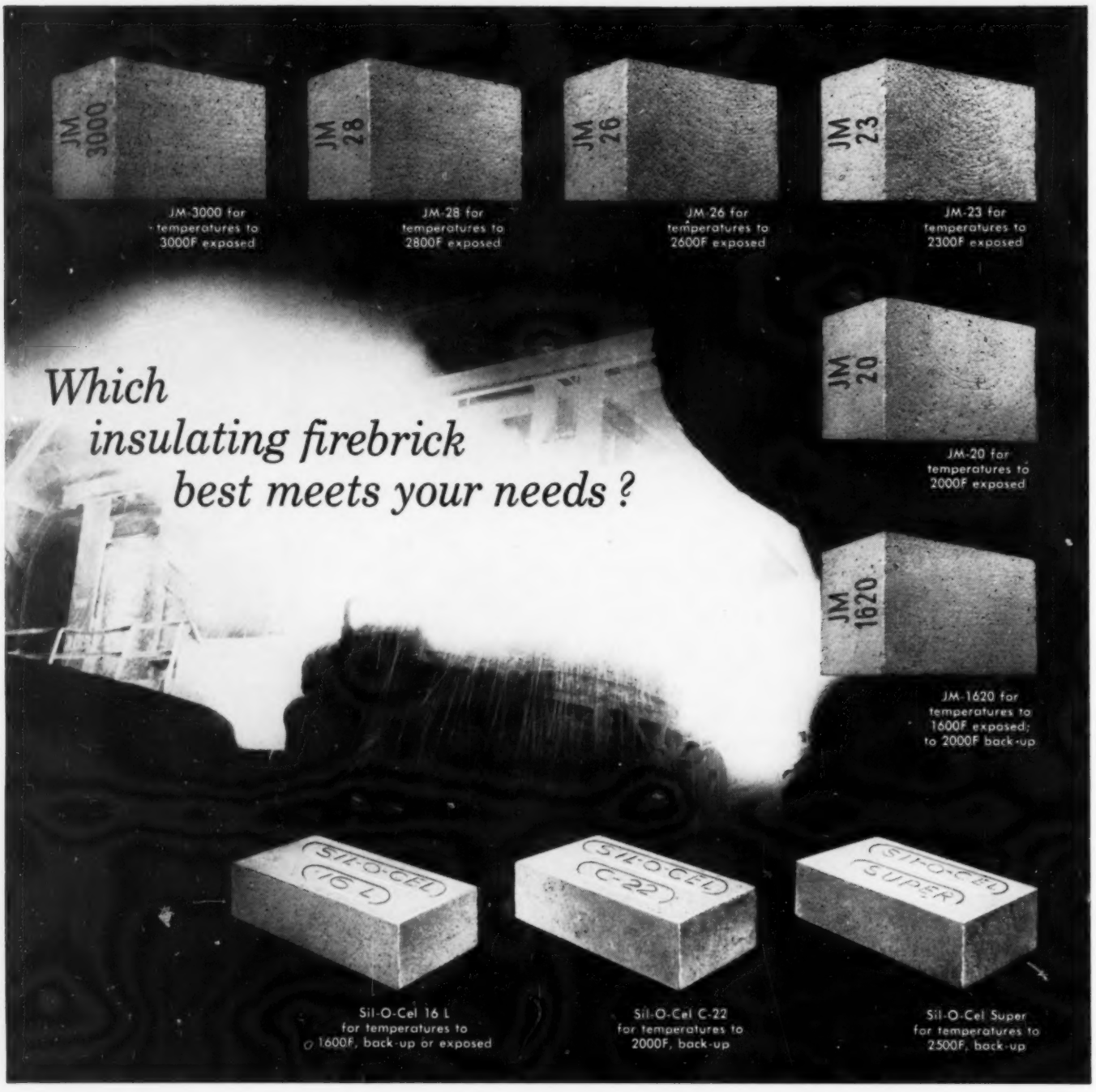
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JM 28
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JM 26
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JM-23 for temperatures to 2300F exposed
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JM-20 for temperatures to 2000F exposed
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JM-1620 for temperatures to 1600F exposed; to 2000F back-up
SIL-O-CEL 16 L
SIL-O-CEL C-22
SIL-O-CEL SUPER
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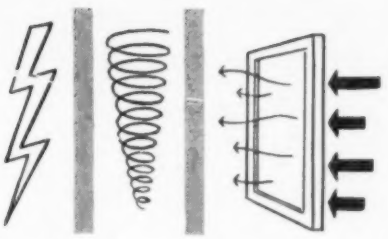

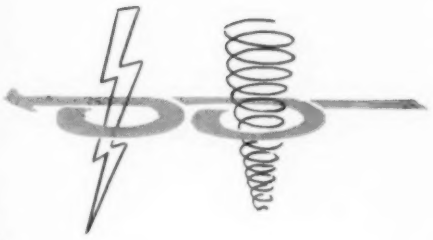

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  Wherever dust-laden gases are formed, moved or discharged.
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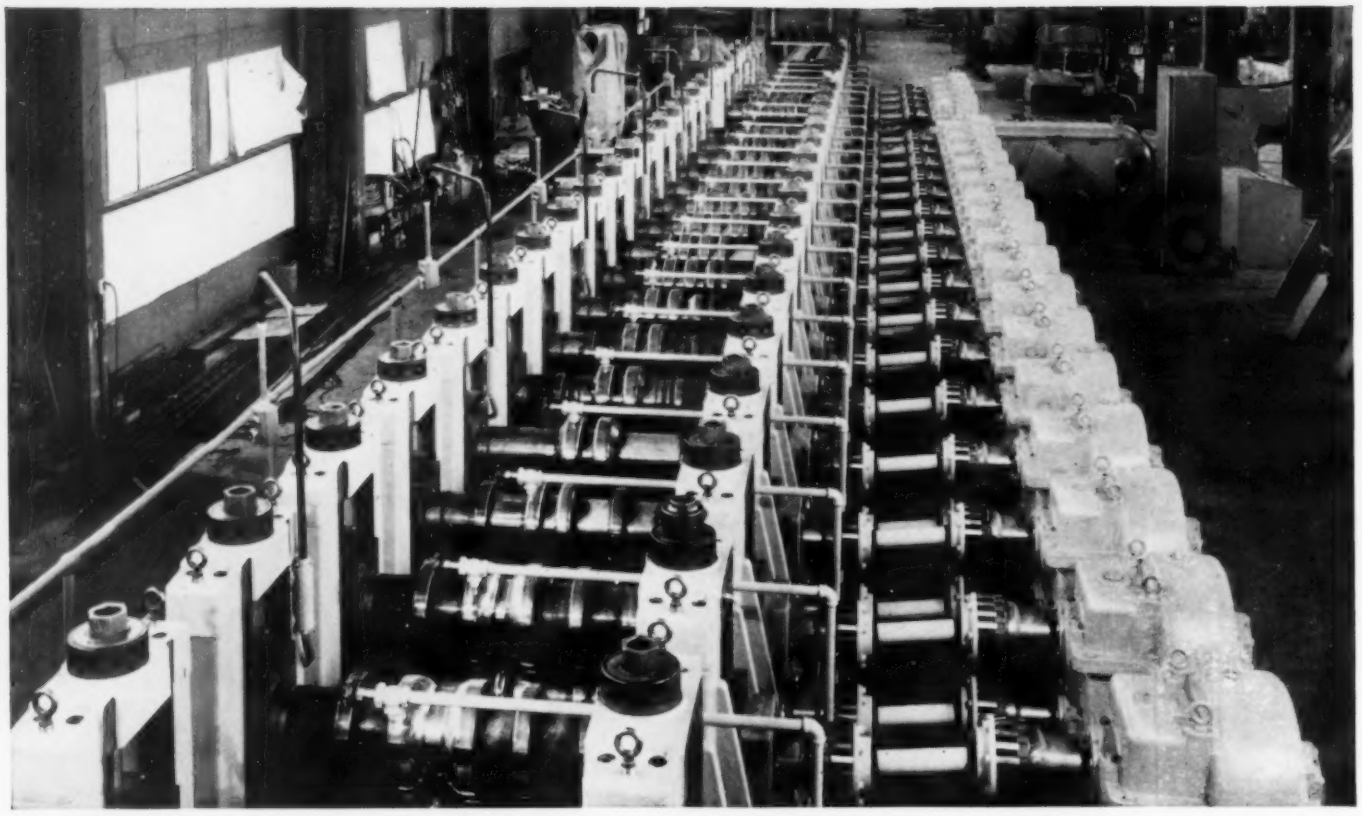

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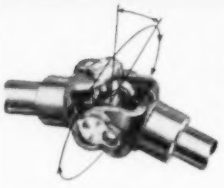
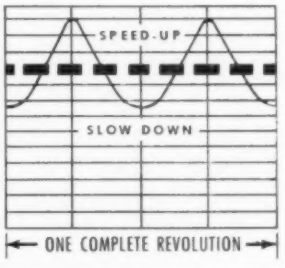
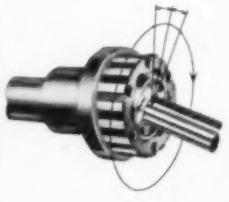


During rotation at a given angle, pin or slipper-type joint speeds up, slows down twice during one revolution.

Solid line shows speed variation for one revolution of pin or slipper-type joint at a critical angle. Note constant velocity of 100% for Rzeppa Joint (dotted line).





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Book Reviews . . .

(Continued from page 223)

thods of Testing, presented at the 58th Annual Meeting of the Society (June 27, 1955), has recently been published by the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. This book contains 170 pages, 6 x 9 in., is bound in heavy paper cover, and sells for $3.50 ($2.65 to members of ASTM). This report contains five additional papers appropriate to the general theme of the symposium, the first in 17 years, as well as the papers (and discussion) comprising the symposium. These are not confined to notched bar testing, but include papers discussing shock tests—impact in parts, components, and complete structures. This broadened scope has encompassed what appears to be a very beneficial enhancement of the practical application of the impact test and of testing at high strain rates, resulting in an excellent balance between theory and experimental results. Many graphs, charts, photographs, reference, and bibliographies present a well rounded account on the subject.

"**ASTM Manual for Rating Motor Fuels by Motor and Research Methods, 1956**" has recently been published by the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. The manual was prepared by ASTM Committee D-2 on Petroleum Products and Lubricants, contains 192 pages, 6 x 9 in., is cloth bound, and sells for $6.75. It contains revised, modernized ASTM methods for determining the knock characteristics of motor fuels by the research and motor methods. The text is amply supplemented and explained by drawings, photographs, numerous tables and charts.

"**Petrographic Modal Analysis—An Elementary Statistical Appraisal,**" by Felix Chayes, has recently been published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. The book contains 113 pages, 6 x 9 in., is cloth bound and sells for $5.50. It is intended for petrographers and statisticians. The book is presented in eleven chapters, discussing the geometrical basis of modal analysis, the modal analysis of banded rocks, methods of measuring relative areas in thin sections, the reproducibility of thin-section anlyses, identification and tabulation conventions, a working definition of analytical error in modal analysis, effect of grain size and area of measurement on analytical error, the control of analytical error by replication, the Holmes effect and the lower limit of coarseness in modal analysis; and contains statistical references and a simple method of calculating "z." Technical jargon has been avoided, and the text is well illustrated with line drawings, equations, and tables.

"**Induction Heating Practice,**" by D. Warburton-Brown, recently published by the Philosophical Library, Inc., 15 East 40th Street, New York 16, N. Y., contains 192 pages 6 x 9 in., is cloth bound, and sells for $10.00. This is a practical handbook on the application of the high-frequency induction heating process for brazing, soldering, hardening, annealing, tempering, and other heating requirements in engineering. After a chapter containing a brief survey of practical aspects, it discusses in succeeding chapters work-coils and inductors, soldering by induction methods, induction brazing, hardening by induction methods, gear hardening, miscellaneous applications, component design for induction heating, locating jigs and handling fixtures. Examples cover a very wide range, from the motor and motor accessory industries to typewriters, gold-melting, electrical components, and precision instruments. Abundant photographs, line drawings, equations, and tables illustrate and explain the text.

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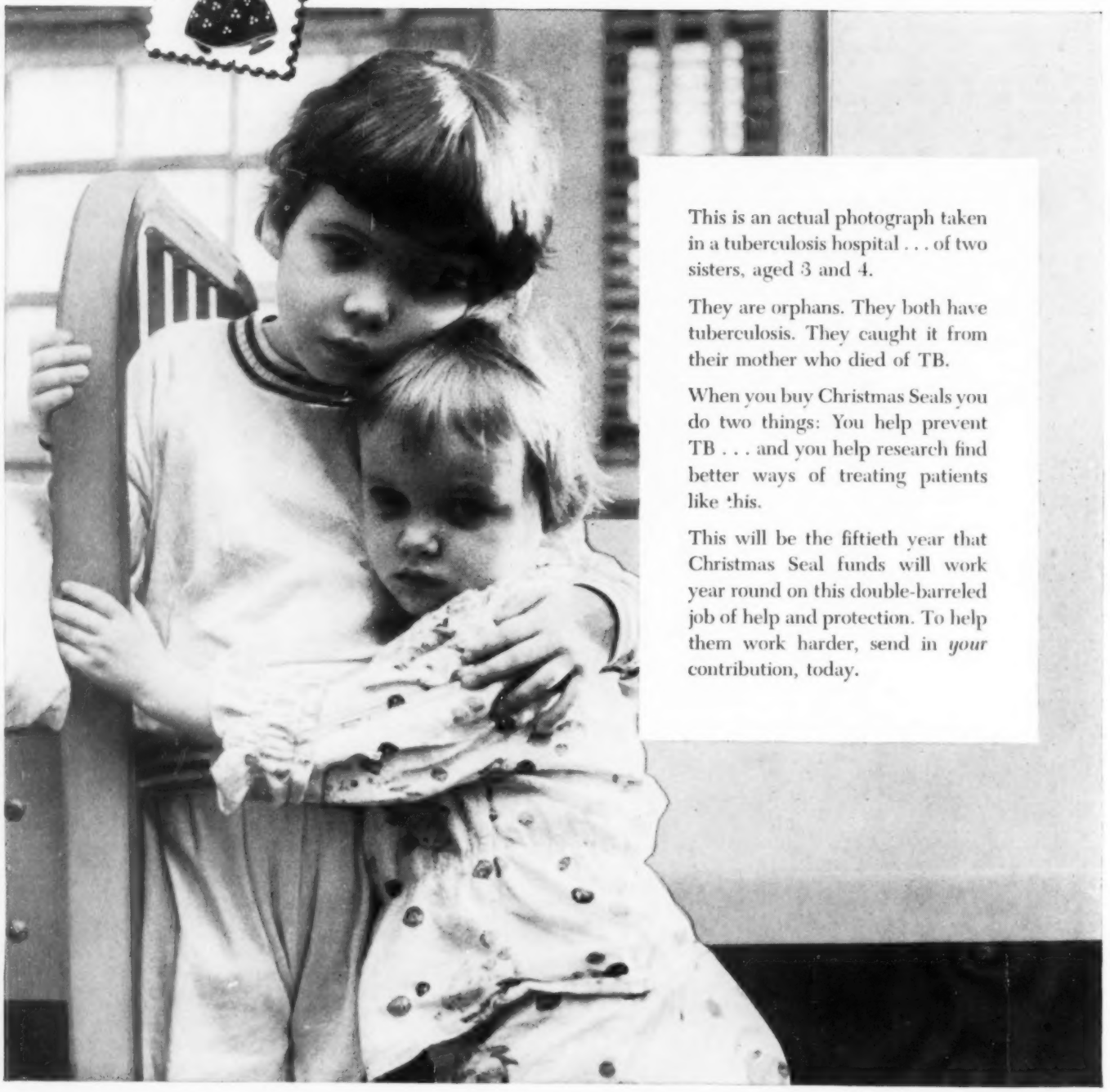

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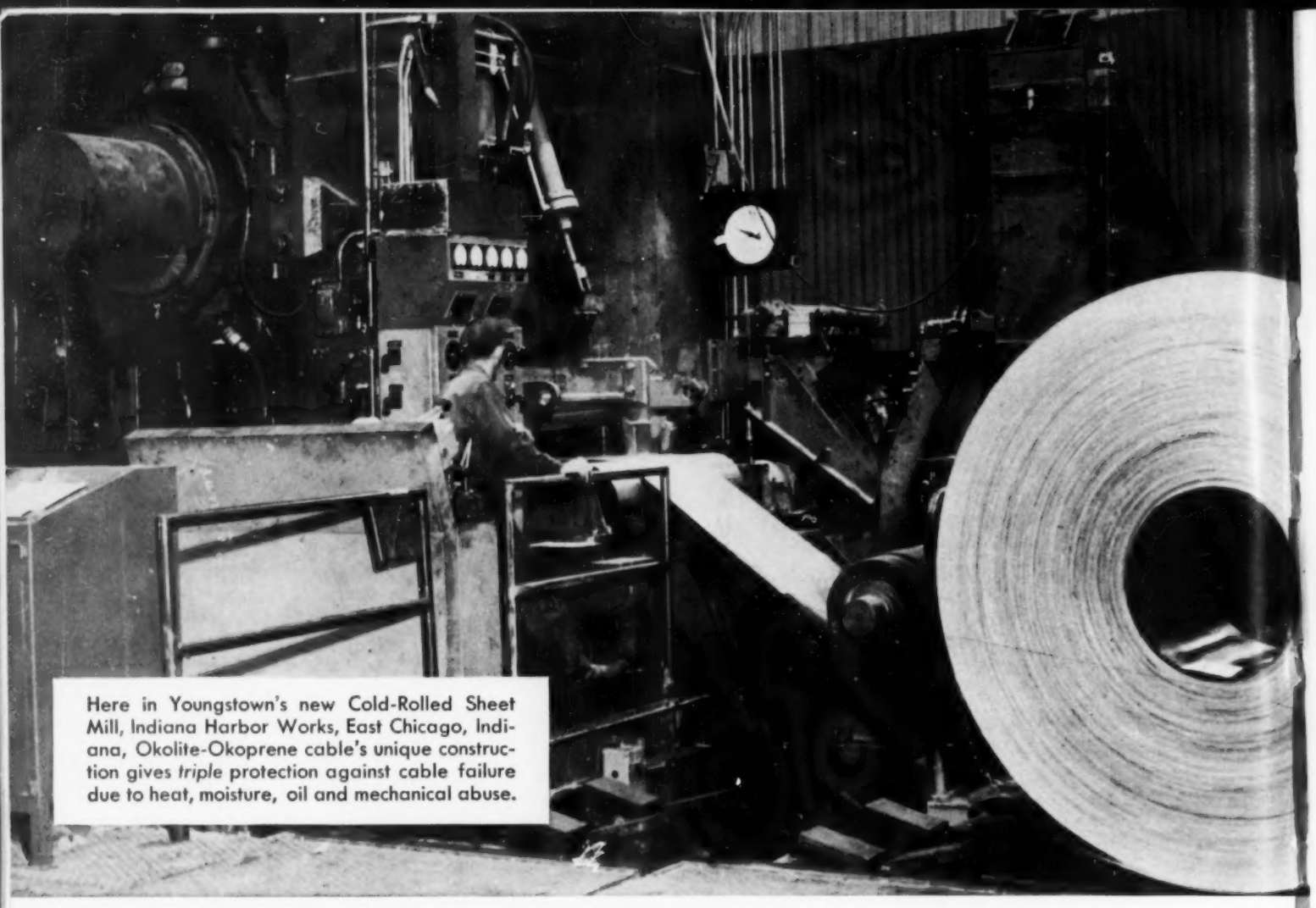

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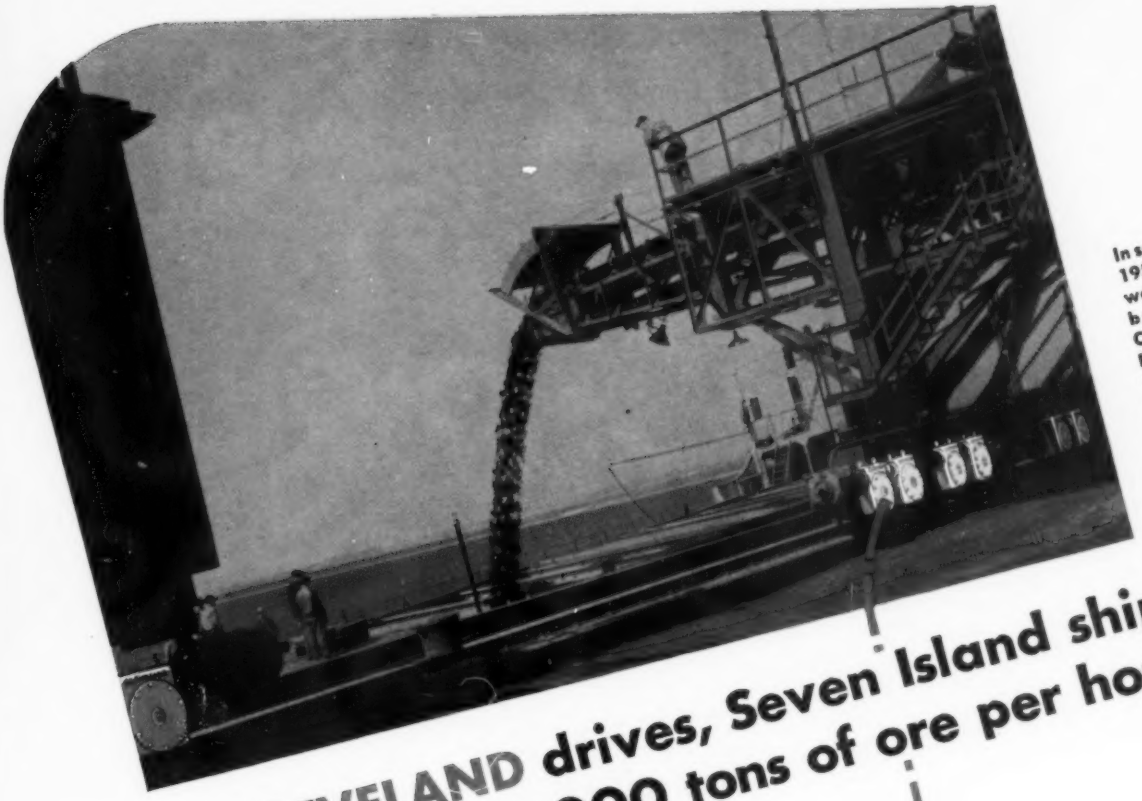

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